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CONTENTS

PAGE

25. Eastern Pacific Expeditions of the New York Zoological Society. XXII. Mollusks from the West Coast of Mexico and Central America. Part I. By LEO GEORGE HERTLEIN, & A. M. STRONG. (Plates I & II) 369

26. On the Electric Powers and Sex Ratios of Foetal *Narcine brasiliensis* (Olfers). By C. M. BREDER, JR., & STEWART SPRINGER 431

27. A Study of the Activities of a Pair of *Galago senegalensis moholi* in Captivity, Including the Birth and Postnatal Development of Twins. By FLORENCE DE L. LOWTHER. (Plates I-VI) 433

28. Diets for a Zoological Garden: Some Results During a Test Period of Five Years. By HERBERT L. RATCLIFFE 463

29. The Biology of the Smoky Shrew (*Sorex fumeus fumeus* Miller). By W. J. HAMILTON, JR. (Plates I-IV; Text-figure 1) 473

30. Social and Respiratory Behavior of Small Tarpon. By ARTHUR SHLAIFER & C. M. BREDER, JR. (Plates I & II; Text-figure 1) 493

31. New Observations on the Blood Group Factors in Simiidi and Cercopithecidae. By P. B. CANDELA, A. S. WIENER & L. J. GOSS 513

32. Muscle Dystrophy in Tree Kangaroos Associated with Feeding of Cod Liver Oil and Its Response to Alpha-Tocopherol. By LEONARD J. GOSS 523

33. Mortality Statistics for Specimens in the New York Aquarium, 1939. By ROSS F. NIGRELLI. (Plates I-III) 525

34. A Comparison of Some Electrical and Anatomical Characteristics of the Electric Eeel, *Electrophorus electricus* (Linnaeus). By R. T. COX, W. A. ROSENBLITH, JANICE A. CUTLER, R. S. MATHEWS & C. W. COATES. (Text-figures 1-7) 553

Index to Volume XXV 563

25.

Eastern Pacific Expeditions of the New York Zoological Society. XXII. Mollusks from the West Coast of Mexico and Central America. Part I.[1]

LEO GEORGE HERTLEIN & A. M. STRONG
California Academy of Sciences.

(Plates I & II).

[This is the twenty-second of a series of papers dealing with the collections of the Eastern Pacific Expeditions of the New York Zoological Society made under the direction of William Beebe. The present paper is concerned with specimens taken on the Templeton Crocker Expedition (1936) and the Eastern Pacific *Zaca* Expedition (1937-1938). For data on localities, dates, dredges, etc., refer to *Zoologica*, Vol. XXII, No. 2, pp. 33-46, and Vol. XXIII, No. 14, pp. 287-298.]

CONTENTS.

Page
Introduction 370
Class Pelecypoda 373
Order Prionodesmacea 373
Superfamily Solemyacea 373
Family Solemyidae 373
Genus *Solemya* Lamarck 374
Subgenus *Acharax* Dall 375
Solemya (Acharax) agassizii Dall 375
Solemya (Acharax) johnsoni Dall 376
Solemya (Acharax) macrodactyla Mabille & Rochebrune 376
Solemya (Acharax) patagonica E. A. Smith 377
Subgenus *Petrasma* Dall 377
Solemya (Petrasma) panamensis Dall 377
Solemya (Petrasma) valvulus Carpenter 378
Superfamily Nuculacea
Family Nuculidae 378
Genus *Nucula* Lamarck 379
Nucula (Nucula) declivis Hinds 380
Nucula (Nucula) exigua Sowerby 381
Subgenus *Ennucula* Iredale 382
Nucula (Ennucula) tenuis Montagu 382
Nucula (Ennucula) cardara Dall 383
Nucula (Ennucula?) linki Dall. 383
Subgenus *Nucolopsis* Woodring .. 383
Nucula (Nucolopsis) schencki Hertlein & Strong, n. sp. 384
Subgenus uncertain:
Nucula agujana Dall 384
Nucula chrysocoma Dall 385
Nucula colombiana Dall 385
Nucula grayi d'Orbigny 385
Nucula iphigenia Dall 386
Nucula panamina Dall 386
Nucula paytensis A. Adams ... 386
Nucula pigafettae Dall 386
Nucula pisum Sowerby 387
Nucula savatieri Mabille & Rochebrune 387
Nucula taeniolata Dall 387
Nucula tanneri Dall 388
Genus *Acila* H. & A. Adams 388
Subgenus *Truncacila* Schenck in Grant & Gale 388
Acila (Truncacila) castrensis Hinds 388
Family Nuculanidae 389
Genus *Nuculana* Link 390
Subgenus *Saccella* Woodring 392
Nuculana (Saccella) acuta Conrad 392
Nuculana (Saccella) callimene Dall 393
Nuculana (Saccella) elenensis Sowerby 393
Nuculana (Saccella) eburnea Sowerby 395
Nuculana (Saccella) gibbosa Sowerby 395
Nuculana (Saccella) impar Pilsbry & Lowe 396
Nuculana (Saccella) laeviradius Pilsbry & Lowe 396
Nuculana (Saccella) taphria Dall 397

[1] Contribution No. 607, Department of Tropical Research, New York Zoological Society.

CONTENTS (continued):

Page
Subgenus *Politoleda* Hertlein & Strong, n. subg. ... 397
Nuculana (*Politoleda*) *polita* Sowerby ... 397
Subgenus *Costelloleda* Hertlein & Strong, n. subg. ... 398
Nuculana (*Costelloleda*) *costellata* Sowerby ... 398
Nuculana (*Costelloleda*) *marella* Hertlein, Hanna & Strong, n. sp. ... 399
Subgenus *Thestyleda* Iredale ... 400
Nuculana (*Thestyleda*) *hamata Carpenter* ... 400
Nuculana (*Thestyleda*) *cordyla* Dall ... 401
Subgenus *Spinula* Dall ... 401
Nuculana (*Spinula*) *calcar* Dall 401
Nuculana (*Spinula*) *calcarella* Dall ... 401
Subgenus *Jupiteria* Bellardi ... 402
Subgenus uncertain:
Nuculana acrita Dall ... 402
Nuculana agapea Dall ... 402
Nuculana bicostata Sowerby ... 403
Nuculana crispa Hinds ... 403
Nuculana cuneata Sowerby ... 403
Nuculana excavata Hinds ... 404
Nuculana hindsii Hanley ... 404
Nuculana lobula Dall ... 404
Nuculana loshka Dall ... 404
Nuculana lucasana Strong & Hertlein ... 405
Nuculana ornata d'Orbigny ... 405
Nuculana oxia Dall ... 405
Nuculana peruviana Dall ... 405
Nuculana pontonia Dall ... 406
Nuculana rhytida Dall ... 406
Genus *Adrana* H. & A. Adams ... 406
Adrana arcuata Sowerby ... 408
Adrana crenifera Sowerby ... 408
Adrana elongata Sowerby ... 409
Adrana exoptata Pilsbry & Lowe 409
Adrana penascoensis Lowe ... 410
Adrana sowerbyana d'Orbigny ... 410
Adrana suprema Pilsbry & Olsson ... 411
Adrana taylori Hanley ... 412
Adrana tonosiana Pilsbry & Olsson ... 412
Genus *Yoldia* Möller ... 412
Subgenus *Katadesmia* Dall ... 413
Yoldia (*Katadesmia*) *vincula* Dall ... 413
Subgenus *Megayoldia* Verrill & Bush ... 414
Yoldia (*Megayoldia*) martyria Dall ... 414
Subgenus *Orthoyoldia* Verrill & Bush ... 414
Yoldia (*Orthoyoldia*) *panamensis* Dall ... 415
Subgenus *Yoldiella* Verrill & Bush 415
Yoldia (*Yoldiella*) *cecinella* Dall 416
Yoldia (*Yoldiella*) *chilenica* Dall ... 416
Yoldia (*Yoldiella*) *dicella* Dall. 416
Yoldia (*Yoldiella*) *granula* Dall 416
Yoldia (*Yoldiella*) *indolens* Dall 417
Yoldia (*Yoldiella?*) *infrequens* Dall ... 417
Yoldia (*Yoldiella*) *leonilda* Dall 417
Yoldia (*Yoldiella?*) *mantana* Dall ... 417
Genus *Cyrilla* A. Adams ... 418
Cyrilla munita Carpenter in Dall 419
Subgenus *Neopleurodon* Hertlein & Strong, n. subg. ... 419
Cyrilla (*Neopleurodon*) *subdolus* Strong & Hertlein ... 420
Genus *Malletia* Desmoulins ... 420
Malletia (*Malletia*) *chilensis* Desmoulins ... 421
Subgenus *Neilo* H. & A. Adams ... 422
Malletia (*Neilo*) *goniura* Dall ... 422
Subgenus *Minormalletia* Dall ... 422
Malletia (*Minormalletia*) *arciformis* Dall ... 423
Malletia (*Minormalletia*) *benthima* Dall ... 423
Subgenus uncertain:
Malletia faba Dall ... 423
Malletia inequalis Dall ... 423
Malletia magellanica E. A. Smith 424
Malletia patagonica Mabille & Rochebrune ... 424
Malletia peruviana Dall ... 424
Malletia truncata Dall ... 424
Genus *Tindaria* Bellardi ... 425
Subgenus *Tindariopsis* Verrill & Bush ... 425
Tindaria (*Tindariopsis*) *sulculata* Gould ... 425
Subgenus uncertain:
Tindaria atossa Dall ... 426
Tindaria compressa Dall ... 426
Tindaria panamensis Dall ... 426
Tindaria mexicana Dall ... 427
Tindaria salaria Dall ... 427
Tindaria smirna Dall ... 427
Tindaria thea Dall ... 427
Tindaria virens Dall ... 428

INTRODUCTION.

Two expeditions to the eastern tropical Pacific were conducted by Mr. Templeton Crocker and Dr. William Beebe under the auspices of the New York Zoological Society. The means of transportation for these trips was Mr. Crocker's yacht *Zaca*. The first of these left San Diego, California, on March 19, 1936. Dredgings were made at many localities from a short distance south of San Diego to Cape San Lucas and into the Gulf of California, north to Santa Inez Bay. Clarion Island in the Revillagigedo group was also visited and some dredgings and shore collections made. At certain places shore collecting was conducted but a large part of the mollusks obtained by this expedition resulted from dredging, mostly from the southern part of the Gulf of California. The depth varied from 1 to 600 fathoms but most of the collection was obtained in less than 100 fathoms. This expedition returned to San Diego, California, on May 25, 1936. A paper by Beebe[2] contains an itinerary, list of stations and nets and dredges used, and a general

[2] Beebe, W. The Templeton Crocker Expedition. II. Introduction, Itinerary, List of Stations, Nets and Dredges. *Zoologica, Sci. Contrib. New York Zool. Soc.*, Vol. 22, pt. 1, April 5, 1937, pp. 33-46, 8 text figs.

account of the trip by the same author[3], appeared in a book entitled "Zaca Venture."

The second expedition by Messrs. Crocker and Beebe left San Diego, California, on November 6, 1937. This cruise took the *Zaca* along western Lower California and the west coast of Mexico as far south as Gorgona Island, Colombia. Dredging and shore collecting on this trip yielded much fine research material. The *Zaca* returned to California and the party disbanded at Balboa on April 5, 1938. An account of the itinerary, list of stations, nets and dredges on this trip is contained in a paper by Beebe[4].

The present collections, then, are almost entirely from tropical and subtropical western North and Central America between 30° and 3° North Latitude. Collecting over such an extensive area has naturally brought to light many interesting occurrences, and a number of new species.

Several important extensions in range were discovered during the work. Especially noteworthy are those species heretofore known from more northern latitudes but now found to range south to Cape San Lucas. Also, numerous species, previously known to occur in more southern latitudes were found in the Gulf of California. An illustration of this is the discovery in the Gulf of *Cancellaria cumingiana* Petit, heretofore known only from Ecuador. Another interesting occurrence is that of a single valve of *Cardium magnum* Linnaeus, a species well known off Florida, which was found at Santa Inez Bay. It seems possible that this may have been transported to the west coast by some fortuitous means.

Through an arrangement with Dr. Beebe the mollusks were submitted to the authors for identification and description. Types of new species and figured specimens have been deposited in the type series of the California Academy of Sciences; duplicates of some of the other species and certain unique specimens were retained in the same institution for the purpose of comparative studies of tropical west American mollusks now under way by the authors. The bulk of the collection accompanied by identifications has been returned to Dr. Beebe of the New York Zoological Society.

Numerous papers contain records of species inhabiting the Gulf of California but the present collection revealed many additional ones not heretofore known to live in that region. There are also a very considerable number of forms previously unknown. Although it has been generally recognized that the Gulf of California contains one of the richest known molluscan faunas, the meticulous care taken by Messrs. Crocker and Beebe in recording locality data makes this collection one of the most important ever made in the area.

Scope and Plan of Present Report.

The preparation of a paper on the present collections offered problems which have required considerable time. No checklist containing the majority of the species known to occur between San Diego and Panama has been published. Several papers dealing with the mollusks of this region exist but any systematic work required consultation of many scattered references and even in these many species have never been illustrated. After due consideration and consultation the authors decided to prepare the paper with the idea in mind that it should be useful not only as a checklist of the present collection but also containing references and illustrations. We therefore have prepared a systematic report with all pertinent references to each

[3] Beebe, W. Zaca Venture (Harcourt Brace & Co., New York City, New York). 1938, 303 pp. + I-XVI. 23 illustrations.

[4] Beebe, W. Eastern Pacific Expeditions of the New York Zoological Society, XIV. Introduction, Itinerary, List of Stations, Nets and Dredges of the Eastern Pacific *Zaca* Expedition, 1937-1938. *Zoologica, Sci. Contrib. New York Zool Soc.*, Vol. 23, pt. 3, September 28, 1938, pp. 287-298, (2 maps pp. 290, 291).

species gathered together in the synonymy. The total lack of a complete checklist of the tropical west American mollusks has necessitated a compilation of all the species known to have been described or cited as occurring in that region. Although it would not be possible in the time available to monograph or even give a critical review of all the species, the great utility of a complete catalogue justifies, in our opinion, the inclusion herein of as complete a census as possible. In some cases we have included additional species which are not known to occur in the tropics but which are related to tropical forms, or which for systematic reasons it seems desirable to include. Keys to the genera of certain of the families, and, where information is adequate, keys to species, have been included. However, in many cases, present knowledge does not justify an attempt to furnish a key. The present unstable nomenclature[5] of mollusks has led the authors to adopt a conservative course in dealing with nomenclatorial problems in connection with this work. Illustrations are planned for all species represented in the collection which are heretofore unillustrated or of which the illustration is not readily available. The range, type locality, repertory of the type where known to us, collecting stations, notes on the species and descriptions of new species are also included. At present it is planned that the entire work will appear at intervals, each part to include one or more families, beginning with the Pelecypoda. In the final part of the paper we hope to present general observations on the collection as a whole and remarks regarding significant features observed regarding distribution; and if feasible, a bibliography of many of the important papers which it is necessary to consult in a study of mollusks of tropical western North America.

At the beginning of this work it was planned that Dr. G. Dallas Hanna, Curator of the Department of Paleontology of the California Academy of Sciences, could collaborate in this work. Unfortunately the work had only begun when duties called him to Alaska and elsewhere which then left the preparation to the present authors. A few species were described during the early stages of the work and in these we have happily been able to include Dr. Hanna as a co-author.

ACKNOWLEDGEMENTS.

We wish here to thank Mr. Templeton Crocker, owner of the yacht *Zaca*, for his generosity and interest which made this paper possible. His collecting and careful recording of locality data have been of great help in work on this collection. To Dr. William Beebe we extend our thanks for his unfailing interest and cooperation throughout this work. His collecting and recording of locality information is a model of its kind. To Dr. G. Dallas Hanna we extend our thanks for his cooperation and unfailing help in advising us regarding many problems which have arisen during the preparation of the paper. His advice and help have been generously available at all times and are greatly appreciated by the authors. Mr. A. G. Smith, Berkeley, California, Dr. U. S. Grant IV, of the University of California at Los Angeles, and Dr. H. G. Schenck and Dr. A. M. Keen of Stanford University, have furnished information regarding certain of the species. The secretarial work of Miss Winifred O'Neill and Miss Alta Holton and the preparation of photographs by Mr. Frank L. Rogers incident to the preparation of this portion of the report is herewith acknowledged. This was done during the course of Federal Works Progress Administration Project No. 8569.

[5] Henderson, J. Our Unstable Biological Classification and Nomenclature. Presidential Address, Fourth Annual Meeting of the American Malacological Union at Stanford University, June 25-28, 1934, pp. 1-13.

Other papers useful in dealing with nomenclatorial problems are: Procedure in Taxonomy, including a Reprint of the International rules of Zoölogical Nomenclature with Summaries of Opinions Rendered to date, completely Indexed. By E. T. Schenk and J. H. McMasters. Stanford University Press, Stanford University, California, 1936, VII + 1-72. Terminology of Types. By D. L. Frizzell. *Amer. Midl. Nat.*, Vol. 14, no. 6, 1933, pp. 637-668.

Class Pelecypoda.

The pelecypods or bivalve shells are well known to collectors and systematists. Oysters and scallops are examples of edible pelecypods of economic importance. Marine species occur in all oceans. The total number is not exactly known but there are perhaps about 8,000 species. They are most numerous on the coasts of continents or on land masses which have formerly been connected with continental land masses. About 500 species are known to occur between Bering Sea and San Diego, California, and at least an equal or greater number exist between San Diego and Peru. The largest of all mollusks is the giant clam, *Tridacna gigas* Linnaeus[6], which attains a length of 54 inches and a weight of more than 500 pounds. Some excellent manuals used in the classification and general arrangement of pelecypods are those of Tryon[7], Chenu[8], Fischer[9], Woodward[10], Dall[11] and Thiele[12]. In general, although with some exceptions, we have followed the arrangement used by Dall. The importance of the hinge in classification has been discussed by Neumayr[13] and by Dall[14]. The structure of shells has been discussed by Böggild[15] and others, and the coloration has been discussed by Bennett[16]. A useful general bibliography of literature dealing with the Pelecypoda is found in Dall's article on Mollusks in Eastman's Translation of Zittel's Textbook of Palaeontology and in recent papers on bivalves by Haas[17]. Additional

Order Prionodesmacea.

Superfamily Solemyacea.

Family Solemyidae.

The family Solemyidae is usually placed first in systematic arrangement of the pelecypods. The shell characters are quite different from the following group, the Nuculidae, and as pointed out by some authors, there is little evidence of relationship between the two groups. The gill-structure of the Solemyidae is believed by some writers to be due probably to specialization and not a remnant of a generalized style.

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6 See Hedley, C. A Revision of the Australian Tridacna. *Rec. Australian Museum*, Vol. 13, no. 4, April 12, 1921, pp. 163-172, pl. 27-34. See especially pp. 168-170. See also *Mem. Australian Mus.* 3, pt. 8, 1899, p. 505, and E. A. Smith, *Proc. Malacol. Soc. London*, Vol. 3, 1898, p. 112.

7 Tryon, G. W. Structural and Systematic Conchology. Volume 3, 1884, Pelecypoda, pp. 116-353, pls. 104-133.

8 Chenu, J. C. Manuel de Conchyliologie, Vol. 2, 1862, pp. 1-199, 1015 figs. in text.

9 Fischer, P. Manuel de Conchyliologie, 1880-1887, pp. 1-1369, 23 pls. Pélécypodes, pp. 897-1187, pls. 16-23.

10 Woodward, S. P. Manual of the Mollusca. Reprint of Fourth Edition (1880), 1910, Conchifera, pp. 393-507, pls. 16-23. Ap. to Manual of Mollusca by R. Tate, 1910, Conchifera, pp. 64-81.

11 Dall, W. H. Text-Book of Palaeontology by K. von Zittel. Edited by C. R. Eastman, Vol. 1, 1913. Pelecypoda, pp. 422-507, Figs. 637-836 in text.

12 Thiele, J. Handbuch der systematischen Weichtierkunde, (Verlag von Gustav Fischer. Jena), Teil 3, 1934, Bivalvia, pp. 782-948, figs. 788-867. Also, Handwörterbuch der Naturwissenschaften, Zweite Auflage, Bd. 1, 1931, Bivalvia, pp. 996-1010, figs. 1-8. See also Bivalvia (Paläontologie) by E. Jaworski, pp. 1010-1026, figs. 1-43.

13 Neumayr, M. Zur Morphologie des Bivalvenschlosses. *Sitzungsber. Akad. Wiss. Wien*, Bd. 88, Abt. 1, 1883, pp. 385-419, 2 pls. ———Beiträge zu einer Morphologischen Eintheilung der Bivalven. *Denkschr. Akad. Wiss. Wien*, Bd. 58, 1891, pp. 701-801.

14 Dall, W. H. Tertiary Mollusks of Florida. A new classification of the Pelecypoda, etc. *Trans. Wagner Free Inst. Sci.*, Vol. 3, pt. 3, March, 1895, pp. 486-566.

15 Böggild, G. B. The Shell Structure of the Mollusks. *D. Kgl. Danske Vidensk. Selsk. Skrifter Naturbidensk. og Math. Afd.*, 9 Raekke, II, 2, 1930, pp. 233-325, 15 pls., 10 figs. in text. See also Schenck, H. G., Literature on the Shell structure of Pelecypods. *Bull. Mus. Hist. Nat. Belg.*, Vol. 10, no. 34, 1934, pp. 1-20.

16 Bennett, E. W. Coloration of Mollusca in relation to Light. *Rec. Canterbury Mus.*, Vol. 3, no. 3, November 23, 1928, pp. 185-197.

17 Haas, F. Bivalvia (Muscheln) H. G. Bronns Klassen und Ordnungen des Tier-reichs, Bd. 3, Abt. III, 1 Lfrg., Leipzig, 1929, pp. 1-176; Bd. 3, Abt. III, 2 Lfrg., 1929, pp. 1-292. With bibliography; Bd. 3, Abt. III, 3 Lfrg., 1931, pp. 177-384; Bivalvia. Dr. H. G. Bronns Klassen und Ordnungen des Tier-reichs, Bd. 3, Abt. III, 4 Lfrg., Leipzig, 1933, pp. 385-544. Also pp. 12-141. Short bibliography; Bd. 3, Abt. III, 1 Lfrg., 1937, pp. 1-208; Bd. 3, Abt. III, 2 Lfrg., 1938, pp. 209-466.

references which deal with the fauna upon which this paper is based will be found in succeeding pages.

Genus **Solemya** Lamarck.

Solemya Lamarck, Anim. s. Vert., Vol. 5, 1818, p. 488. Species in original list: *Solemya australis* and *Solemya mediterranea*. ———Dall, *Nautilus*, Vol. 22, no. 1, May, 1908, p. 1. "Type *S. australis* Lamarck." ———Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 361. *S. australis* Lamarck considered to be the type. ———Grant & Gale, *Mem. San Diego Soc. Nat. Hist.*, Vol. 1, 1931, p. 109. Type: *Solenomya mediterranea* Lamarck=*Solemya mediterranea* Lamarck= *Solemya togata* (Poli).

Solenimya Lamarck, Bowdich, Elem. Conch., Pt. 2, 1822, p. 8. "*Solenimya*. (*Solemya*. Lam.) M." Sole species: *Solenimya australis* cited as fig. 17.

Solenomya Lamarck, Menke, Synop. Meth. Moll., 1830, p. 119. "(*Solemya*, Lam.)" Sole species: *Solenomya mediterranea* Lamarck. ———Children, *Quart. Jour. Lit. Sci. and Arts*, Vol. 14, January 1823, p. 300 (reprint p. 27). Reprint by Kennard, Salisbury and Woodward, *Smithson. Misc. Coll.*, Vol. 82, no. 17, July 11, 1931, p. 7. Type species: *S. mediterranea* Lamarck.

Type (designated by Children): *Solenomya mediterranea* Lamarck. [=*Solemya mediterranea* Lamarck, Anim. s. Vert., Vol. 5, 1818, p. 489. Ref. to "Poli, test. 2, p. 42, et vol. 1. tab. 15, f. 20"; "Solen. Encycl. pl. 225, f. 4." "Habite la Méditerranée, dans le sable." Referred to *Solenomya togata* Poli by Bucquoy, Dautzenberg & Dollfus, Moll. Mar. Roussillon, Vol. 2, 1898, p. 718, pl. 92, figs. 8, 9, 10. Mediterranean; Adriatic; Atlantic; Senegal; Madeira].

Shell elongate, *Solen*-shaped, gaping at each end, epidermis dark, horny and extending beyond the ventral margins; umbos posterior; ligament amphidetic, chiefly internal; hinge edentulous with an obliquely inclined chondrophore, below which is an internal rib on the inner surface of the valve; pallial line obscure. Outer layer of shell composed of long prismatic cells, nearly parallel with surface and mingled with dark cells as in *Pinna;* inner layer also cellular.

Dall[18] has published a revision of the Solemyidae.

Solemya has been recorded from Paleozoic to Recent (Carboniferous and possibly Silurian to Recent). The genus has been cited from the Eocene of California by Clark & Woodford[19] and it also occurs from upper Oligocene or lower Miocene to Recent in western North America. *Solemya* (*Solemya*) *lomitensis* Olsson[20] has been described from the Oligocene of Peru, and Marwick[21] has recorded the genus from the lower Miocene of New Zealand. It also occurs in the Cenozoic of various other parts of the world.

In *Solemyarina* Iredale[22] with the type *S. velesiana* Iredale "The median rib is not curved, but is angulated posteriorly, while the anterior portion of the ligament is small and linear and the posterior portion is small and sub-linear, the posterior muscle scar free" (Iredale, 1939).

Zesolemya was proposed by Iredale[23] for the New Zealand species *Solemya parkinsonii* Gray.

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[18] Dall, W. H., A Revision of the Solenomyacidae. *Nautilus*, Vol. 22, no. 1, May, 1908, pp. 1-2. See also, Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, pp. 361-366.

[19] *Solemya* sp., Clark & Woodford, *Univ. Calif. Publ. Bull. Dept. Geol. Sci.*, Vol. 17, no. 2, December 31, 1927, p. 85, pl. 14, fig. 1. Univ. Calif. Loc. 3162. North side of Deer Valley, north of Mt. Diablo, Mt. Diablo Quadrangle, California. Meganos formation; Eocene.

[20] *Solemya* (*Solemya*) *lomitensis* Olsson, *Bull. Amer. Paleo.*, Vol. 17, no. 63, June 5, 1931, p. 127 (31), pl. 15 (3), fig. 5. "Lomitos," Peru; Oligocene.

[21] Marwick, J., *Geol. Surv. New Zealand, Palaeo. Bull.* No. 13, 1931, p. 48, pl. 1, fig. 1.

[22] *Solemyarina* Iredale, *Rec. Austral. Mus.*, Vol. 18, no. 4, June 29, 1931, pp. 202, 231. "I introduce *Solemyarina* for these small species, designating *velesiana* as type." Sydney, Australia. ———Iredale, Brit. Mus. (Nat. Hist.) Great Barrier Reef Exped. 1928-29. Sci. Repts., Vol. 5, no. 6, Moll. Pt. 1, 1939, p. 232. "Orthotype: *Solemya velesiana* Iredale."

[23] *Zesolemya* Iredale, Brit. Mus. (Nat. Hist.) Great Barrier Reef Exped. 1928-29. Sci. Repts., Vol. 5, no. 6, Moll. pt. 1, 1939, p. 233.

KEY TO THE SPECIES OF *Solemya*.

A. Ligament internal ..... (subgenus) *Petrasma*
  a. Anterior end with 8 or 9 obscure rays ..... *panamensis*
  aa. Anterior end with fine radial striae only ..... *valvula*

B. Ligament external ..... (subgenus) *Acharax*
  a. Dorsal margin with a heavy callous ..... *patagonica*
  aa. Dorsal margin without accessory callous
    b. Entire surface with subequally spaced radiating rays ..... *johnsoni*
    bb. Surface with central area smooth or with obsolete rays
      c. Posterior end evenly rounded ..... *agassizii*
      cc. Posterior end meeting hinge line and basal margin at rounded right angles ..... *macrodactyla*

Subgenus ***Acharax*** Dall.

Acharax Dall, *Nautilus*, Vol. 22, no. 1, May, 1908, p. 2. "Type *S. johnsoni* Dall." ———Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 364.

Type (by original designation): *Solemya johnsoni* Dall.

Ligament opisthodetic, wholly external, visible internally only where it crosses the gap between the margins of the valves. Nymphs without props (Dall).

Acharax has been recorded from Oligocene to Recent.

Solemya (Acharax) agassizii Dall.

S[*olemya*]. *agassizii* Dall, *Nautilus*, Vol. 22, no. 1, May, 1908, p. 2. "Off Tillamook Bay, Oregon, south to Aguja Point, Peru, in 1036-1800 fathoms."

Solemya (*Acharax*) *agassizii* Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 365, pl. 16, fig. 10. U. S. S. *Albatross* station 3360, "Gulf of Panama, in 1672 fathoms, sand, bottom temperature 36°.4 F." Also at other stations from 1588, 1740, 1772, and 1793 fathoms; off Aguja Point, Peru, in 1036 fathoms; range; Gulf of California to off Aguja Point, Peru. ——— Zetek, *Rev. Nueva*, Nos. 1 & 2, 1918, p. 37. Panama.—I. S. Oldroyd, *Stanford Univ., Publ. Univ. Ser. Geol. Sci.*, Vol. 1, 1924, p. 9, pl. 40, fig. 11 (under subgenus *Acharax*). Original records cited.

Acharax agassizii Dall, Dall, *U. S. Nat. Mus., Bull.* 112, 1921, p. 9. Tillamook, Oregon, to Point Aguja, Peru.

Type Locality: Gulf of Panama, in 1672 fathoms. Type No. 106,885 U. S. Nat. Mus.

Range: Off Tillamook, Oregon, to Aguja Point, Peru, in 1036 to 1800 fathoms.

The shell of *Solemya agassizii* is ornamented by about five or six anterior radial channels rather than from nine to twelve on *S. johnsoni*. *S. agassizii* differs from *S. macrodactyla* Mabille & Rochebrune, a more southern species, in the presence of a smooth middle area on the valves, as well as the proportionately shorter posterior end, and much larger size. *S. grandis* Verrill & Bush[24], an Atlantic species, has a shorter and wider shell.

Solemya (*Acharax*) *dalli* Clark[25] from the lower Miocene or upper Oligo-

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[24] *Solemya grandis* Verrill & Bush, *Proc. U. S. Nat. Mus.*, Vol. 20, [No. 1139.], 1898, p. 885, pl. 86, figs. 1 and 2. "Two good specimens and some fragments, at four stations, between N. lat. 39° 58′ 30″, W. long. 70° 30′, and N. lat. 37° 24′, W. long. 74° 17′, in 300 to 1,600 fathoms, 1880-1884."

[25] *Solemya dalli* Clark, *Univ. Calif. Publ. Bull. Dept. Geol. Sci.*, Vol. 15, no. 4, January 5, 1925, p. 73, pl. 8, fig. 2. L.S.J.U. Loc. NP. 120. "Shales outcropping in sea cliffs west of West Twin River for distance of ¾ mile, Twin, Washington." ———Tegland, *Univ. Calif. Publ. Bull. Dept. Geol. Sci.*, Vol. 23, no. 3, October 11, 1933, p. 103, pl. 4, figs. 1, 2, 3, 4, 5, 6, 7, 8, 9, 10. Type locality. Also from Restoration Point, Blakeley formation, near Seattle, Washington. Upper Oligocene.

cene of Washington is a somewhat similar species and *Solemya tokunagai* Yokoyama[26] and *S. yessoensis* Kanehara[27], from the Tertiary of Japan, are members of the same group.

Solemya (*Acharax*) *belenensis* Olsson[28] has been described from the Oligocene of Peru.

Solemya (Acharax) johnsoni Dall.

Solemya johnsoni Dall, *Proc. U. S. Nat. Mus.*, Vol. 14, 1891, p. 189. "U. S. steamer *Albatross*, station 3010, off coast of Lower California, in 1,005 fathoms." ———Dall, *Proc. U. S. Nat. Mus.*, Vol. 17, 1894, p. 712, pl. 25, fig. 1. Coast of Ecuador in 1,740 fathoms; Gulf of Panama, in 1,672-1,793 fathoms; Gulf of California in 1,000-1,588 fathoms; Straits of Fuca, in deep water. ———Keep, West Amer. Shells (The Whitaker & Ray Co.,) San Francisco, 1904, p. 19, fig. 8. Deep water as far north as Puget Sound. ———Dall, *Nautilus*, Vol. 22, no. 1, 1908, p. 2. Puget Sound to Panama Bay in 60 to 1740 fathoms. ———Keep, West Coast Shells, (The Whitaker & Ray-Wiggin Co.) San Francisco, 1911, p. 24, fig. 10. Same locality as cited 1904. Edit. by Baily, 1935, p. 45, fig. 20 (as *Solemya* (*Acharax*) *johnsoni*). Oregon to Panama. ———Zetek, *Rev. Nueva*, Nos. 1 & 2, 1918, p. 37. Panama. ———I. S. Oldroyd, *Stanford Univ. Publ. Univ. Ser. Geol. Sci.*, Vol. 1, 1924, p. 9, pl. 14, fig. 1 (under subgenus *Acharax*). Type locality cited. Range: Oregon to Panama.

Solenya [Typ. error] *johnsoni* [Dall], Pilsbry, *Nautilus*, Vol. 5, no. 4, August, 1891, p. 47.

Solenomya johnsoni Dall, Rogers, The Shell Book, (Doubleday, Page & Co., Garden City, New York), 1913, p. 368. Puget Sound Southward.

Acharax johnsonii Dall, Dall, *U. S. Nat. Mus., Bull.* 112, 1921, p. 9 (under genus *Solemya*). Oregon to Panama.

Type Locality: Off the coast of Lower California, in 1,005 fathoms.

Range: Puget Sound to Panama.

There are nine to twelve anterior radial channels on the shell of *Solemya johnsoni*, while there are only five or six such channels on the similar *S. agassizii*.

Solemya (Acharax) macrodactyla Mabille & Rochebrune.

Solemya macrodactyla Mabille & Rochebrune, Miss. Sci. Cap Horn, Vol. 6, Zool., pt. 2, 1891, p. H109, pl. 8, fig. 4. "*Hab.* Baie Orange." ———Dall, *Nautilus*, Vol. 22, no. 1, May, 1908, p. 2. ———Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, 1908, p. 364. Orange Harbor, Patagonia, north to Chiloë Island, southwest Chile, in 20 to 369 fathoms.

Type Locality: Orange Harbor, Patagonia.

Range: Orange Harbor and north to Chiloë Island, southwest Chile, in 20 to 369 fathoms.

This southern species, *Solemya macrodactyla*, bears a resemblance to *Solemya agassizii* which occurs farther north, but the posterior end is less rounded than it is in that species. Mabille & Rochebrune compared *S. mac-*

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[26] *Solemya tokunagai* Yokoyama, *Jour. Coll. Sci. Imp. Univ. Tokyo*, Vol. 45, Article 5, March 21, 1925, p. 31, pl. 6, figs. 1, 2, 3. "Shiogu in Tatsuta; Tsuchibashi in Kadōno; Enamura Quarry." Pliocene. ———Kanehara, *Jap. Jour. Geol. & Geogr.*, Vol. 14, nos. 3 & 4, 1937, p. 156, pl. 15, figs. 10, 11 (as *Solemya* (*Acharax*) *tokunagai*). "Near Mōrae, Atsuta-gun, Ishikari." Oiwake Series; upper Miocene to Pliocene.

[27] *Solemya* (*Acharax*) *yessoensis* Kanehara, *Jap. Jour. Geol. & Geogr.*, Vol. 14, nos. 3 & 4, October, 1937, p. 155, pl. 15, fig. 12. "Near Mōrai, Atsuta-gun, Ishikari." Oiwake Series; upper Miocene to Pliocene.

[28] *Solemya* (*Acharax*) *belenensis* Olsson, *Bull. Amer. Paleo.*, Vol. 17, no. 63, June 5, 1931, p. 127 (31), pl. 15 (3), fig. 7. "Heath formation, Lobos, Pajarabobo." Peru; Oligocene.

rodactyla to *S. borealis* Totten which occurs from Halifax, Nova Scotia, to Connecticut, and to *S. parkinsonii* Gray[29] of New Zealand. Dall has pointed out that *Solemya macrodactyla* may ultimately be relegated to the synonymy of *S. patagonica* E. A. Smith.

Solemya (Acharax) patagonica E. A. Smith.

Solemya patagonica E. A. Smith, Sci. Res. Voy. Challenger, Zool., Vol. 13, 1885, pp. 24, 208, pl. 11, figs. 1, 1a. "*Habitat.* ———Station 311, off west coast of South Patagonia, in 245 fathoms." ———Dall, *Nautilus*, Vol. 22, no. 1, May, 1908, p. 2. ———Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 364. West coast of Patagonia.

Type Locality: Off west coast of Chile, in 245 fathoms.

Range: West coast of Chile.

At the time of description of *Solemya patagonica*, E. A. Smith compared the species to *S. parkinsonii* Gray of New Zealand. Dall considered it likely that *S. macrodactyla* Mabille & Rochebrune might be relegated to the synonymy of *S. patagonica*, but stated that the type of *S. patagonica* appeared to be abnormally callous dorsally.

E. A. Smith (*Ann. & Mag. Nat. Hist.*, Ser. 7, vol. 18, October, 1906, p. 253) has cited *S. patagonica* from off India, and Melvill & Standen (*Proc. Zool. Soc. London*, November 13, 1906, p. 793) have cited it from the Gulf of Oman in the Arabian Sea. We have not seen specimens from that region.

Subgenus **Petrasma** Dall.

Petrasma Dall, *Nautilus*, Vol. 22, no. 1, May, 1908, p. 2. "Type *S. borealis* Totten." ———Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 363.

Type (by original designation): *Solemya borealis* Totten. [*Amer. Jour. Sci.*, Ser. 2, Vol. 26, July, 1834, p. 366, pl. [unnumbered], fig. 1. h, i. "Inhabits the coast of Rhode Island." Also illustrated by M. Smith, East Coast Mar. Shells (Edwards Bros., Ann Arbor, Michigan), 1937, p. 25, fig. 29a. Nova Scotia to Connecticut].

Ligament internal but not exposed internally in front of the chondrophore.

Solemya (Petrasma) panamensis Dall.

S[*olemya*]. *panamensis* Dall, *Nautilus*, Vol. 22, no. 1, May, 1908, p. 2. "extends from off Santa Barbara, Cal., to Panama Bay."

Solemya (*Petrasma*) *panamensis* Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 366. "U. S. S. 'Albatross,' station 2799, Panama Bay, in 29½ fathoms, mud." Also off Santa Barbara, California, in 68 fathoms.

Solemya panamensis Dall, Zetek, *Rev. Nueva*, Nos. 1 & 2, 1918, p. 37. Panama. ———I. S. Oldroyd, *Stanford Univ. Publ. Univ. Ser. Geol. Sci.*, Vol. 1, 1924, p. 10, pl. 9, fig. 4. Original record cited. ———Pilsbry & Lowe, *Proc. Acad. Nat. Sci. Philadelphia*, Vol. 84, 1932, p. 141. "On mud flats at extreme tide, rare. La Paz." ———Lowe, *Trans. San Diego Soc. Nat. Hist.*, Vol. 8, no. 6, 1935, p. 27. Punta Penasco, Sonora, Mexico, dredged in 10 fathoms. ———Strong, *Proc. Calif. Acad. Sci.*, Ser. 4, Vol. 23, no. 12, 1937, p. 192. San Martin Island, Lower California, Mexico.

[29] *Solemya parkinsonii* Gray, Voy. Erebus & Terror, 1874, p. 6, pl. 3, fig. 1 ———Suter, Man. New Zealand Moll. (Wellington, New Zealand), 1913, p. 830, pl. 58, fig. 1. Throughout New Zealand, in mud about 6 inches below the surface; Kermadec Islands; Milford Sound, in 100-120 fathoms.

Petrasma panamensis Dall, Dall, *U. S. Nat. Mus., Bull.* 112, 1921, p. 9. Santa Barbara, California, to Panama.

Type Locality: Panama Bay, 29½ fathoms. Type No. 110,678 U. S. Nat. Mus.

Range: Santa Barbara, California, to Panama.

This is more expanded in front and less sharply truncate in front than *S. agassizii* of the same length, and they may be separated at once by the difference in the hinges. *S. valvulus* Carpenter is a much smaller species and has no anterior prop to the chondrophore (Dall).

Solemya (Petrasma) valvulus Carpenter.

Solemya valvulus Carpenter, *Ann. & Mag. Nat. Hist.*, Ser. 3, Vol. 13, April, 1864, p. 311. Cape St. Lucas. Reprint in *Smithson. Misc. Coll.*, No. 252, 1872, p. 210. ———Carpenter, *Rept. Brit. Assoc. Adv. Sci.* for 1863 (issued August, 1864), p. 618. Reprint in *Smithson. Misc. Coll.*, No. 252, 1872, p. 104. ———Dall, *Nautilus*, Vol. 22, no. 1, May, 1908, p. 2. San Pedro, California, to the Gulf of California. ———Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 364. San Pedro, California, to the Gulf of California. ———I. S. Oldroyd, *Stanford Univ. Publ. Univ. Ser. Geol. Sci.*, Vol. 1, 1924, p. 11, pl. 40, fig. 10 (under subgenus *Petrasma*). Type locality cited. Range: San Pedro, California, to the Gulf of California. ———Lowe, *Trans. San Diego Soc. Nat. Hist.*, Vol. 8, no. 6, 1935, p. 27. Punta Penasco, Sonora, Mexico, dredged in 10 fathoms.

Solemya (Petrasma) valvulus Carpenter, Lamy, *Journ. de Conchyl.*, Vol. 57, no. 3, 1909, p. 208. Gulf of California.

Petrasma valvulus Carpenter, Dall, *U. S. Nat. Mus., Bull.* 112, 1921, p. 9. San Pedro, California, to the Gulf of California.

Type Locality: Cape San Lucas, Lower California.

Range: San Pedro, California, to Punta Penasco, Sonora, Mexico.

The shell of *Solemya valvulus* is small, thin, transparent and attains a length of about 20 mm. It is ornamented by radial slender brownish lines which are finely striate posteriorly, distantly spaced on the medial portion of the shell, and short, broad, and bifurcate anteriorly. The chondrophore is without props.

Superfamily Nuculacea.

Family Nuculidae.

The family Nuculidae is an ancient one and has representatives in the Paleozoic. *Praenucula* Pfab[30] assigned to this family has been described from the Silurian of Bohemia. In the Nuculidae the pallial impression is entire, due to the lack of development of siphons. The shells are entirely closed, not gaping, and the inner shell-layer is pearly. The family occurs in both shallow and deep water. A few occur in tropical waters but most of the species occur in temperate and boreal waters.

Two papers by Schenck[31] on the classification of nuclid pelecypods may be consulted regarding the nomenclature of members of this family. Dr. Schenck has kindly examined a number of specimens of *Nucula* and *Nuculana* in the present collection and has furnished us notes on certain of the species.

[30] *Praenucula* Pfab, Palaeontogr., Bd. 80, Abt. A, Lief. 4-6, April, 1934, p. 234. "Typus des Genus: *P. dispar expansa* n. var." p. 235, pl. 3, figs. 10, 11, 15a, 15b. Osek.

[31] Schenck, H. G. Classification of Nuculid Pelecypods. *Bull. Mus. Roy. d'Hist. Nat. Belgique*, Vol. 10, no. 20, June, 1934, 78 pp., 5 pls. ———Schenck, H. G. Revised Nomenclature for some Nuculid Pelecypods. *Jour. Paleo.*, Vol. 13, no. 1, pp. 21-41, 4 pls., January, 1939.

Genus **Nucula** Lamarck.

Nucula Lamarck, *Mem. Soc. Hist. Nat. Paris*, Vol. 1, 1799, p. 87. Sole species: *Arca nucleus* Linnaeus. ———Schenck, *Bull. Mus. Roy. d'Hist. Nat. Belg.*, Vol. 10, no. 20, 1934, p. 18, pl. 1, fig. 8; pl. 3, fig. 2; pl. 4, figs. 4, 4a, 4b; pl. 5, figs. 1, 1a. "(Type by monotypy: *Arca nucleus* Linné.)"

Type (by monotypy): *Arca nucleus* Linnaeus. [Syst. Nat., Ed. 10, 1758, p. 695. "*Habitat in* Europa." Illustrated by Schenck, *Bull. Mus. Roy. d'Hist. Nat. Belg.*, Vol. 10, no. 20, 1934, p. 18, pl. 1, fig. 8; pl. 3, fig. 2; pl. 4, figs. 4, 4a, 4b; pl. 5, figs. 1, 1a. ———Schenck, *Proc. Malacol. Soc. London*, Vol. 21, pt. 4, March, 1935, fig. 1 (p. 260)].

Shell closed, not gaping; profile ovate-trigonal; a "pouting" of the escutcheonal area, which the radial ribs do not cross; beaks opisthogyrate, appressed; prodissoconch unornamented; radial ribs faint, low, wide and flat, often difficult to see on the middle part of the shell, but they are more distinct near the ventral margin where they form the "pectinate margin"; interspaces narrow, about one-tenth the width of the ribs; interior nacreous; pallial line simple; two subequal adductor muscle scars and additional muscle scars; longer (anterior) row of teeth arched, with 16 ± to 24 ± teeth; the shorter (posterior) row straight with 7 ± to 11 ±; axis of chondophore forms an arc of a circle of which the arcuate dorsal margin is a part (Schenck).

Key to the Species of *Nucula*[32].

A. Outer surface smooth
- a. Periostracum olive
  - b. Periostracum dark olive
    - c. Length less than 10 mm
      - d. Shape subcordate, umbos weak, length 8 mm., height 4 mm. ..... *tenuis*
      - dd. Shape subtrigonal, umbos prominent, length 6 mm., height 5 mm. ..... *linki*
    - cc. Length over 20 mm., solid, thick ..... *panamina*
  - bb. Periostracum pale olive
    - e. Length less than 10 mm., shape, ovate ..... *colombiana*
    - ee. Length 14-21 mm. *savatieri*
- aa. Periostracum greenish or black
  - f. Periostracum greenish
    - g. Anterior hinge teeth 8, posterior 18 ..... *cardara*
    - gg. Anterior hinge teeth 5, posterior 11 ..... *grayi*
  - ff. Periostracum nearly black ..... *agujana*

B. Outer surface sculptured
- a. Concentric sculpture only
  - b. Length less than 10 mm. ..... *pisum*
  - bb. Length over 20 mm. ..... *tanneri*
- aa. Radial sculpture present
  - c. Radial sculpture faint
    - d. Length less than 5 mm.
      - e. Anterior teeth less than 15

[32] In the case of species which are not illustrated and which we have not seen, the key is based upon descriptions.

KEY TO THE SPECIES OF *Nucula* (continued):

f. Sculpture definitely reticulate, concentric strong, anterior teeth 9, posterior 5 ..... *schencki*

ff. Sculpture not reticulate, concentric weak, anterior teeth 10, posterior 6 ..... *chrysocoma*

ee. Anterior teeth 17, posterior 9 ..... *paytensis*

dd. Length over 10 mm.

g. Anterior hinge teeth 6, posterior 10 ..... *taeniolata*

gg. Anterior hinge teeth 7, posterior 15-17 ..... *pigafettae*

cc. Radial sculpture strong

h. Length less than 10 mm.

i. Concentric sculpture heavier, regular rugae ..... *exigua*

ii. Concentric sculpture fine, irregular ..... *declivis*

hh. Length over 30 mm. *iphigenia*

Nucula (Nucula) declivis Hinds.

Plate I, Figures 1, 2, 3, 6, 7.

Nucula declivis Hinds, *Proc. Zool. Soc. London*, December, 1843, p. 98. "*Hab.* .....?" ———Hinds, Zool. Voy. Sulphur, Moll. Pt. 3, 1844 (January, 1845, on cover of Pt. 3), p. 63, pl. 18, fig. 8. "Inhab. .....?" ———Hanley, Thes. Conch., Vol. 3, 1860, *Nucula*, p. 154, pl. 230 (*Nuculidae*, pl. 5), fig. 147. "Hab. .....?" ———Sowerby, Conch. Icon., Vol. 18, *Nucula*, October, 1870, sp. 31, pl. 4, fig. 31. "*Hab.* .....?" ———Dall, *Proc. U. S. Nat. Mus.*, Vol. 37, 1909, p. 250. "Panama to Magellan Straits." —Zetek, *Rev. Nueva*, Nos. 1 & 2, 1918, p. 37. Panama. ———Lowe, *Trans. San Diego Soc. Nat. Hist.*, Vol. 8, no. 6, 1935, p. 27. Punta Penasco, Sonora, Mexico. ———Strong & Hertlein, *Allan Hancock Pacific Exped.* (*Univ. South. Calif.*), Vol. 2, no. 12, 1939, p. 183. Bahia Honda, and off Taboga Island, Panama.

Type Locality: Original locality not known. Type locality here designated as off Taboga Island, Panama, in 3-9 fathoms.

Range: Punta Penasco, Sonora, Mexico, to Panama. [?] Panama to Magellan Straits (Dall).

Collecting Stations: Mexico: Santa Inez Bay, Gulf of California (145-D-1,-3). 4-15 fathoms, sand; Manzanillo Bay (184-D-2). 30 fathoms, gravelly sand bottom; Nicaragua: Corinto (200-D-19 and beach). 12-13 fathoms, mangrove leaves; Costa Rica: (203-D-1,-3). 12-15 fathoms, sand and shelly mud bottom.

This species has a small, smooth, oblique shell ornamented by very fine radial striations. In the original description it is stated that the ventral margin is crenulate, and that the species is "a still more oblique shell than *N. pisum*, to which it is closely allied." From the original illustrations alone it would be difficult to separate *N. declivis* from *N. pisum* Sowerby although Sowerby's species appears to be less oblique. *N. pisum* was originally described from Valparaiso, Chile. Hanley and Dall have considered *N. semiornata* d'Orbigny[33] to be synonymous with *N. pisum*. Specimens of *N. declivis* from the Gulf of California resemble, in general features, *N. crenulata* Adams[34] from Florida.

[33] *Nucula semi-ornata* d'Orbigny, Voy. Amér. Mérid., Vol. 5, 1846, p. 624, pl. 84, figs. 27, 28, 29. "Nous l'avons recueillie dans la baie de San Blas, au nord de la Patagonie, où elle vit au niveau des plus basses marées. Elle y est très-rare. M. Darwin l'a recontrée fossile à la baie Blanche."

[34] *Nucula crenulata* A. Adams, *Proc. Zool. Soc. London*, 1856, p. 52. "*Hab.* Guadaloupe Mus. Cuming." ———Hanley Thes. Conch., Vol. 3, 1860, p. 154, pl. 229, (*Nuculidae*, pl. 4), figs. 134, 135. "Guadaloupe." ———Sowerby, Conch. Icon., Vol. 18, *Nucula*, October, 1870, sp. 25, pl. 4, fig. 25. "*Hab.* Guadeloupe."

Nucula (Nucula) exigua Sowerby.

Plate I, Figures 4, 5.

Nucula exigua Sowerby, *Proc. Zool. Soc. London* for 1832 (issued March 13, 1833), p. 198. "*Hab.* ad Columbiam Occidentalem (Bay of Caraccas)." [Ecuador Lat. 0° 35′S.] "A single specimen found in sandy mud at nine fathoms depth." ———Sowerby, Conch. Illustr., 1833, *Nuculae*, p. 6, pl. 16, figs. 24, 24*. "Bay of Caraccas." ———Müller, Synop. Test. Viv., 1836, p. 192. Type locality cited. ——— Hanley, Cat. Rec. Bivalve Shells, p. 172, 1843, p. 376, ?1856, Suppl. pl. 20, fig. 13, 1856. W. Colombia. ———d'Orbigny, Voy. Amér. Mérid., Vol. 5, 1846, p. 625. Original locality cited. ———C. B. Adams, *Ann. Lyceum Nat. Hist. New York*, Vol. 5, 1852, p. 479. Panama. Also earlier records cited. ———Carpenter, Cat. Mazatlan Shells, February, 1856, p. 145. (as *Nucula ? exigua*). Mazatlan, Mexico. Also earlier records cited. ———Carpenter, *Rept. Brit. Assoc. Adv. Sci.* for 1856 (issued 1857), pp. 249, 277, 311. Gulf of California; Central America; Panama; Bay of Caraccas, Ecuador. ———Hanley, Thes. Conch., Vol. 3, 1860, p. 154, pl. 229, (*Nuculidae*, pl. 4), fig. 136. "Bay of Caracas. W. Columbia." ———Carpenter, *Proc. Zool. Soc. London*, 1863, p. 364. Reprint in *Smithson. Misc. Coll.*, No. 252, 1872, p. 200. C. B. Adams' record cited. ———Sowerby, Conch. Icon., Vol. 18, *Nucula*, October, 1870, sp. 26, pl. 4, fig. 26. "*Hab.* West Columbia." ———Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, 1908, p. 370. Bay of Panama (Cuming); off Acapulco, Mexico, in 660 fathoms; near the Galapagos Islands, in 812 fathoms; off Aguja Point, Peru, in 1036 fathoms; west cost of Patagonia, in 122 and 194 fathoms. ———Dall, *Proc. U. S. Nat. Mus.*, Vol. 37, 1909, p. 250. Acapulco, Mexico, to Ecuador and to the Magellanic region. ———Zetek, *Rev. Nueva*, Nos. 1 and 2, 1918, p. 51. Zoogeographical province of Panama. ———Olsson, *Nautilus*, Vol. 37, no. 4, 1924, p. 126. Salinas, Ecuador. Common. ———E. K. Jordan, *Contrib. Dept. Geol. Stanford Univ.*, Vol. 1, no. 4, 1936, p. 112. Magdalena Bay, Lower California, Pleistocene.

Nucula (*Nucula*) *exigua* Sowerby, Schenck, *Jour. Paleo.*, Vol. 13, no. 1, 1939, p. 36, pl. 6, figs. 1-8, 11. Type loc. cited. Also western North America.

Type Locality: Bay of Caraccas, Ecuador, in 9 fathoms, in sandy mud. Type in Brit. Mus. (Nat. Hist.).

Range: San Bartolome Bay [Turtle Bay], Lower California, and Gulf of California to Ecuador. [?] Magellanic region (Dall).

Collecting Station: Nicaragua: Corinto (200-D-19). 12-13 fathoms, mangrove leaves.

The shell of *Nucula exigua* is ornamented by concentric and radial ornamentation but the concentric is much the stronger. It is a small shell averaging not over 5 mm. in length. A strongly projecting lunular area just under the beaks appears to be a characteristic feature of the species. These differences are well shown on photographs of the type of *N. exigua* shown to us by H. G. Schenck.

Some authors have considered *N. exigua* to be identical with *N. suprastriata* Carpenter (in Arnold)[35] but Schenck has given reasons for considering them to be distinct species. The radial ribbing on *N. suprastriata* is not well developed and usually is present only near the ventral margin. The lunule and escutcheon is more deeply impressed on *N. suprastriata* and it is a larger shell averaging 5.5 to 6 mm. in length. *Nucula cahuitensis* Olsson[36] from the Miocene of Costa Rica was compared to *N. exigua* by Olsson.

Nucula paytensis A. Adams, bears considerable similarity to *N. exigua*. Photographs of the type of the species described by Adams show a more rounded outline and broader projecting lunular area but we are not certain whether these differences are constant characters which can be used to separate the two species.

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[35] *Nucula* (*Nucula*) *suprastriata* Carpenter in Arnold, *Mem. Calif. Acad. Sci.*, Vol. 3, 1903, p. 96, pl. 18, fig. 6. "Upper San Pedro series, Los Cerritos" Upper Pleistocene. Also at Spanish Bight, San Diego, California, upper Pleistocene. Rare in lower San Pedro of Deadman Island, lower Pleistocene, and in the upper San Pedro Series of San Pedro, California, upper Pleistocene. ———Schenck, *Jour. Paleo.*, Vol. 13, no. 1, 1939, p. 36, pl. 6, figs. 9, 10, 12, 13. Various localities in the Pleistocene of southern California.

[36] *Nucula cahuitensis* Olsson, *Bull. Amer. Paleo.*, Vol. 9, Bull. No. 39, June 21, 1922, p. 343 (171), pl. 21 (18), figs. 21-24. "Gatun Stage: Zone G, Saury Creek," Costa Rica. Miocene.

Subgenus **Ennucula** Iredale.

Ennucula Iredale, *Rec. Australian Mus.*, Vol. 18, no. 4, June 29, 1931, pp. 202, 231. "Type *Nucula obliqua* Lamarck. ———Schenck, *Bull. Mus. Roy. d'Hist. Nat. Belg.*, Vol. 10, no. 20, 1934, p. 37, pl. 3, figs. 4, 4a, 4b; pl. 4, figs. 3, 3a, 3b. Type: *Nucula obliqua* Lamarck. ———Cotton & Godfrey, Moll. South Australia, Pt. 1. Handbook of Flora and Fauna of South Australia, issued by South Australian Branch of Brit. Sci. Guild. Adelaide, 1938, p. 40. "Genotype ———*E. obliqua* Lamarck." ———Iredale, Brit. Mus. (Nat. Hist.) Great Barrier Reef Exped. 1928-29 Sci. Repts. Vol. 5, no. 6, Moll., pt. 1, 1939, p. 235. Orthotype: *Nucula obliqua* Lamarck.

Type (by original designation): *Nucula obliqua* Lamarck. [Anim. s. Vert., Vol. 6, 1819, p. 59. "Habite les mers australes, au cap aux Huîtres." ———Illustrated by Schenck, *Bull. Mus. Roy. d'Hist. Nat. Belg.*, Vol. 10, no. 20, 1934, p. 37, pl. 3, figs. 4, 4a, 4b; pl. 4, figs. 3, 3a, 3b. "Cap aux Huitres, Nouvelle Hollande."]

The type species of *Nucula* is *nucleus* Linné, a European species which differs appreciably from antipodean shells so classed, the latter having a notably oblique chondrophore, above which the teeth become much smaller, and the angle of opposition of the two rows of teeth is scarcely marked; further, the edge of the European shell is strongly denticulate, whereas ours is practically smooth (Iredale).

Nucula (Ennucula) tenuis Montagu.

Arca tenuis Montagu, Test. Brit., Suppl., 1808, p. 56, pl. 29, fig. 1. "on the shore near *Dunbar*," England.

Nucula tenuis Montagu, Forbes & Hanley, Hist. Brit. Moll., Vol. 2, 1853, p. 223, pl. 47, fig. 6; and (animal) pl. P, fig. 5. England and North Atlantic, Massachusetts. Also Pliocene. ———Hanley, Thes. Conch., Vol. 3, 1860, p. 161, pl. 229 (Nuculidae, pl. 4), figs. 140, 141. Britain, W. Europe. ———Sowerby, Conch. Icon., Vol. 18, *Nucula*, October, 1870, sp. 20, pl. 3, fig. 20. "*Hab.* Britain, Europe." ———I. S. Oldroyd, *Stanford Univ. Publ. Univ. Ser. Geol. Sci.*, Vol. 1, no. 1, 1924, p. 13, pl. 5, fig. 12; pl. 37, fig. 4. Point Barrow, Alaska, to Coronado Islands, California. Circumboreal. Pliocene at San Pedro and San Diego, California. ——— Antevs, *För. Geol. Fören. i Stockholm*, Bd. 50, Heft 4, 1928, p. 493.

Nucula (*Nucula*) *tenuis* Montagu, Grant & Gale, *Mem. San Diego Soc. Nat. Hist.*, Vol. 1, 1931, p. 111. Earlier records cited. "Miocene" [Pliocene] of St. Paul Island, and Nushagak Island, Alaska (Dall), and Recent. Circumboreal.

Nucula (*Ennucula*) *tenuis* Montagu, Schenck, *Jour. Paleo.*, Vol. 13, no. 1, January, 1939, p. 33, pl. 8, figs. 1-4, 9, 12, 14, 15. Earlier records cited.

Not *Pronucula tenuis* Powell, *Rec. Canterbury Mus.*, Vol. 3, no. 2, December 14, 1927, p. 119, pl. 22, figs. 1, 2. Southwest of Otago, New Zealand, in 100 fathoms.

Type Locality: Near Dunbar, England, on shore.

Range: Northern Europe. Northeastern North America. Circumboreal. Point Barrow, Alaska, to Cedros Island, Lower California.

Collecting Station: Mexico: East of Cedros Island (126-D-12). 45 fathoms, crushed shell and mud bottom.

One specimen of *Nucula tenuis* was dredged in Lat. 28° 20′ N., Long. 115° 10′ 30″ W., one mile east of Cedros Island, Lower California. Heath[37] has recently studied the soft parts of this species.

This appears to be a wide-ranging form. According to Schenck some of the specimens dredged off British Columbia agree exactly with specimens of the species from the North Sea. Schenck has placed *Nucula tenuis* in the subgenus *Ennucula* Iredale. The bathymetric range of the species given by Antevs is 2 to 1,200 meters.

[37] Heath, H., *Mem. Mus. Roy. d'Hist. Nat. Belgique*, Ser. 2, Fasc. 10, 1937, pp. 4, 9, etc., pl. 3, figs. 19, 20, 21, 22, 26; pl. 4, figs. 31, 33, 34; pl. 5, fig. 44; pl. 9, fig. 81. Behring Sea, in 36 fathoms.

Nucula (Ennucula) cardara Dall.

Nucula cardara Dall, *Proc. U. S. Nat. Mus.*, Vol. 52, December 27, 1916, p. 394. "Station 5673, in 1090 fathoms, mud, off San Diego, California." ———Dall, *U. S. Nat. Mus., Bull.* 112, 1921, p. 10. Monterey, California, to Lower California, in deep water. ———I. S. Oldroyd, *Stanford Univ. Publ. Univ. Ser. Geol. Sci.*, Vol. 1, 1924, p. 12. Type locality and range same as cited by Dall. ———Keen, Check List West North Amer. Mar. Moll. (Stanford Univ. Press), 1937, p. 23. Lat. 30°-37°N.

Nucula (Ennucula) cardara Dall, Schenck, *Jour. Paleo.*, Vol. 13, no. 1, January, 1939, p. 34, pl. 5, figs. 12, 14, 18, 21. Type locality cited.

Type Locality: Off San Diego, California, in 1090 fathoms, mud. Type No. 265905 U. S. Nat. Mus.

Range: Monterey, California, to Lat. 30° N., Lower California, in deep water.

Shell elongate-ovate, thin, polished, light olive green in color; hinge with 8 anterior and 18 posterior teeth; margins of valves smooth. Length, 16 mm.; height, 11.5 mm.; diameter, 8 mm.

Nucula (Ennucula?) linki Dall.

Nucula linki Dall, *Proc. U. S. Nat. Mus.*, Vol. 52, December 27, 1916, p. 394. "Station 3034, 24 fathoms, mud; off Point Fermin, Lower California." ———Dall, *U. S. Nat. Mus., Bull.* 112, 1921, p. 10. Queen Charlotte Sound to Guaymas, Mexico. ———I. S. Oldroyd, *Stanford Univ. Publ. Univ. Ser. Geol. Sci.*, Vol. 1, 1924, p. 12. Type locality and range same as cited by Dall. ———Keen, Check List West North Amer. Mar. Moll. (Stanford Univ. Press), 1937, p. 23, Lat. 23°-55° N.

Nucula (Ennucula?) linki Dall, Schenck, *Jour. Paleo.*, Vol. 13, no. 1, January, 1939, p. 33, pl. 5, figs. 2, 6, 11, 15. Type locality cited.

Type Locality: Off Point Fermin, California, in 24 fathoms, mud. [According to Schenck, not from off Point Fermin, Lower California, as originally cited by Dall]. Type No. 107649 U. S. Nat. Mus.

Range: Queen Charlotte Sound, British Columbia, to Guaymas, Sonora, Mexico.

Shell small, inflated, very inequilateral, subtriangular and of a dark olive color; hinge with six anterior and eleven posterior teeth; valve margins entire. Length, 6 mm.; height, 5 mm.; diameter, 3.6 mm.

Subgenus **Nucolopsis** Woodring.

Nucolopsis Woodring, *Carnegie Inst. Washington, Publ.* No. 366, May, 1925, p. 14. [Cited in caption only. ? Typ. error.].

Nuculopsis Woodring, *Carnegie Inst. Washington, Publ.* No. 366, May, 1925, p. 14. "Type. ———*Nucula (Nuculopsis) hilli* new species." ———Schenck, *Bull. Mus. Roy. d'Hist. Nat. Belg.*, Vol. 10, no. 20, June, 1934, p. 33. Type: *Nucula hilli* Woodring.

Not *Nuculopsis* Girty, *Ann. New York Acad. Sci.*, Vol. 21, 1911, p. 133. "Type species, *Nucula ventricosa* Hall." Pennsylvanian series.

Not *Nuculopsis* Rollier, *Abh. Schweiz. Paläont. Gesell.*, Vol. 38, Part 2, 1912, p. 64. Renamed *Isoleda* by Rollier, *Rev. Crit. Paléozool.*, Vol. 27, no. 1, January, 1923, p. 67. "(G.-T. *Nuc. Palmae* Sow.)." Jurassic.

Type (by original designation): *Nucula (Nuculopsis) hilli* Woodring, *Carnegie Inst. Washington, Publ.* No. 366, May, 1925, p. 14, pl. 1, figs. 2 and 3. Bowden, Jamaica, Miocene.

Shell medium-sized, subelliptical, inequilateral; sculpture consisting of strong concentric rugae; chondrophore long, narrow, oblique, deeply excavated; anterior series of teeth more than twice as long as posterior series;

anterior teeth reduced in size toward chondrophore, posterior teeth not reduced; interior of valve subnacreous; lower inner margin of valve smooth (Woodring).

At the present time the subgenus "*Nucolopsis*" is represented by the type species *Nucula hilli*, in the Miocene of Bowden, Jamaica, and by one species, *N. schencki*, in the Recent fauna of western Mexico.

At the time of description of this subgenus Woodring spelled it *Nucolopsis* in the caption but following that on the same page it is consistently spelled "*Nuculopsis*." There is a prior *Nuculopsis* described by Girty and also one by Rollier. Dr. Schenck is working on the family Nuculidae and is of the opinion that *Nucolopsis* may be regarded as a typographical error for *Nuculopsis*. We have used the original spelling used by Woodring but the name may not be valid, and if not it will be rectified in Schenck's forthcoming work on the Nuculidae.

Nucula (Nucolopsis) schencki Hertlein & Strong, sp. nov.

Plate I, Figures 8, 9, 10.

Shell thin, polished; rather compressed; beaks small; dorsal margin anterior to beaks elevated and broadly rounded; anterior end more acutely rounded; ventral margin and posterior end broadly rounded; sculpture consists of rather closely spaced concentric ribs crossed by faint radiating striae which are weaker on the umbos; lunular area not depressed, area of escutcheon marked only by a very short thin line. Length 2.0 mm., height 1.7 mm., thickness both valves 1.0 mm.

Interior of paratypes reveals a smooth, glossy surface with faint crenulations along the ventral margin corresponding to the exterior striae; chondrophore relatively large, deeply set, elongate, subtriangular, the axis oblique; teeth well developed, about 9 in the anterior series and 5 in the posterior series.

Holotype, from Sta. 195-D-9, dredged in 7 fathoms (12.6 meters) Lat. 15° 44′ 28″ N., Long. 96° 07′ 51″ W., Port Guatulco, Mexico, gray sand and crushed shell bottom.

Nucula schencki sp. nov. resembles *Nucula* ("*Nuculopsis*") *hilli* Woodring[38] described from the Miocene of Jamaica more closely than any Recent west American shell. The more elongate shape, lack of radial striae exteriorly, noncrenulate lower interior margin and greater number of teeth on the Jamaican shell easily separate it from the present species. We have had available photographs of the type specimen of *Nucula hilli* for comparison with our new species. The photographs were furnished by Dr. H. G. Schenck who received them from Dr. Paul Bartsch of the U. S. National Museum.

The new species has been referred to the subgenus *Nucolopsis* because it resembles that group in most of its general characters although it does have very faint crenulations on the interior of the ventral margins.

This species is named for Dr. Hubert G. Schenck of Stanford University in recognition of his work on the Nuculidae.

The subgeneric position of the following species of *Nucula* is uncertain.

Nucula agujana Dall.

Nucula agujana Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 370, pl. 10, figs. 6, 7. U. S. S. *Albatross* station 4654, "twenty-four miles N. 68° W. from Aguja Point, Peru, in 1036 fathoms, mud, bottom temperature 37°.3 F."

[38] *Nucula* (*Nuculopsis*) *hilli* Woodring, *Carnegie Inst. Washington, Publ.* No. 366, May, 1925, p. 14, pl. 1, figs. 2 and 3. Bowden, Jamaica, Miocene.

Type Locality: 24 miles northwest of Aguja Point, Peru, in 1,036 fathoms, mud. Type No. 110,571 U. S. Nat. Mus.

Range: Known only from the type locality.

Shell small, triangular, inequilateral, polished, nearly black with paler olivaceous umbos; hinge with 15 anterior and 9 posterior teeth; margins of the valves smooth. Length, 11 mm.; height, 8 mm.; diameter, 5.75 mm.

Nucula chrysocoma Dall.

Nucula chrysocoma Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 370, pl. 18, figs. 3 and 4. U. S. S. *Albatross* Station 4656, "off the coast of Peru in S. Lat. 6° 55′ and W. Long. 83° 34′, in 2,222 fathoms, green mud, bottom temperature 35°.2 F." Also off Manta, Ecuador, in 401 fathoms, and off Acapulco, Mexico, in 660 fathoms.

Type Locality: Off the coast of Peru, Lat. 6° 55′ S., Long. 83° 34′ W., in 2,222 fathoms, green mud. Type No. 110,572 U. S. Nat. Mus.

Range: Off Acapulco, Mexico, to Peru, in deep water.

Shell small, plump, solid, subtriangular, polished, and of a light yellowish-olive color; sculpture of irregularly spaced impressed concentric lines and fine slightly raised, close-set radial lines; hinge with 10 anterior and 6 posterior teeth; margins of valves entire. Length, 5.0 mm.; height, 4.5 mm.; diameter 3.0 mm.

Nucula colombiana Dall.

Nucula colombiana Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 371. "West coast of Colombia, in Panama Bay at station 2799, in 29½ fathoms." Also in Panama Bay, in 51 fathoms; off Manta, Ecuador, in 401 fathoms; southern Chile, in 122 and in 194 fathoms; off west coast of Patagonia, Lat. 51° 12′ S., in 258 fathoms. ———Dall, *Proc. U. S. Nat. Mus.*, Vol. 37, 1909, p. 250. Panama to Patagonia.

Type Locality: West coast of Colombia, in Panama Bay, in 29½ fathoms. Type No. 110,686 U. S. Nat. Mus.

Range: Panama to west coast of Patagonia in Lat. 51° 12′ S.

Shell small, very inequilateral, ovate, white with a pale olive periostracum, smooth and brilliantly polished; hinge with 14 anterior and 7 posterior teeth; margins of valves smooth. Length, 4.5 mm.; height, 3.0 mm.; maximum diameter, 2.2 mm.

Nucula grayi d'Orbigny.

Nucula obliqua Lamarck, Sowerby, Conch. Illustr., *Nuculae*, 1833, p. 5, pl. 16, fig. 21. "Valparaiso, Mr. Cuming." ———Hanley, Cat. Recent Bivalve Shells, p. 171, 1843, p. 376, 1856?, Suppl. pl. 20, fig. 9, 1856. "Valparaiso, South Seas."

Not *Nucula obliqua* Lamarck, Hist. Nat. Anim. s. Vert., Vol. 6, 1819, p. 59. "Habite les mers australes, au cap aux Huîtres."

Nucula grayi d'Orbigny, Voy. Amér. Mérid., Vol. 5, 1846, p. 625. "Cette espèce, la plus grande que nous connaissions dans les mers du Chili, a été recueillie par nous près de Valparaiso, où elle est rare." New name for "*Nucula obliqua*, Gray (non Lamarck)." ———Hanley, Thes. Conch., Vol. 3, 1860, p. 157, pl. 229 (*Nuculidae*, pl. 4), fig. 126. Chili. ———Hupe, Hist. de Chile, Zool., Vol. 8, 1854, p. 304. ———Sowerby, Conch. Icon., Vol. 18, *Nucula*, October, 1870, sp. 13, pl. 2, fig. 13. "*Hab.* New Zealand." [Not New Zealand]. ———Dall, *Proc. U. S. Nat. Mus.*, Vol. 37, 1909, p. 250. Valparaiso, Chile.

Type Locality: Valparaiso, Chile.

Range: Known only from the vicinity of the type locality.

Shell thin, oval, much longer than broad, with a polished greenish-olive periostracum; margins entire.

Nucula iphigenia Dall.

Nucula iphigenia Dall, *Proc. U. S. Nat. Mus.*, Vol. 18, April 23, 1896, p. 15. "U. S. Fish Commission station 3396, in 259 fathoms, Gulf of Panama; temperature, 47.4°F." ———Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 369, pl. 7, figs. 1 and 4. "Gulf of Panama, in 259 fathoms, hard bottom; temperature, 47.4° F."

Type Locality: Gulf of Panama, in 259 fathoms, hard bottom. Type No. 122,895 U. S. Nat. Mus.

Range: Known only from the type locality.

This fine shell is one of the largest known nuculas, and peculiar from its elongated shape and posterior attenuation. The periostracum seems to have been thin, dull, and yellowish (Dall). The margins of the shell are denticulate. The hinge with about 30 anterior and 15 posterior teeth. Length, 35 mm.; height, 22.5 mm.; diameter, 16 mm.

Nucula panamina Dall.

Nucula panamina Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 368, pl. 6, fig. 11. U. S. S. Albatross, station 3360, "Gulf of Panama, in 1672 fathoms, sand, bottom temperature 42°F."

Type Locality: Gulf of Panama, in 1,672 fathoms, sand. Type No. 122,894 U. S. Nat. Mus.

Range: Known only from the type locality.

Shell large, thick, solid, rather donaciform with dark polished olivaceous periostracum; interior more or less radially striate, but valve margins smooth and entire; hinge with 20 anterior and 10 posterior teeth. Length 22 mm.; height, 16 mm.; diameter, 9 mm.

Nucula paytensis A. Adams.

Nucula paytensis A. Adams, *Proc. Zool. Soc. London*, 1856, p. 51. "*Hab.* Payta, Peru. Mus. Cuming." ———Sowerby, Conch. Icon., Vol. 18, *Nucula*, October, 1870, sp. 23, pl. 3, fig. 23. "*Hab.* Payti, Peru." ———Dall, *Proc. U. S. Nat. Mus.*, Vol. 37, 1909, p. 250. Paita, Peru.

[*Nucula crenulata*] var.? *N. paytensis* A. Adams, Hanley, Thes. Conch., Vol. 3, 1860, p. 154, pl. 230 (*Nuculidae*, pl. 5), figs. 160 and 161. [No locality cited].

Type Locality: Paita, Peru.

Range: Known only from the type locality.

A very oblique, ovate, gibbose species, concentrically grooved and decussately striated (A. Adams).

Nucula pigafettae Dall.

Nucula pigafettae Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 369. U. S. S. *Albatross*, station 2780, "Magellan Straits, in 369 fathoms, mud, bottom temperature 47°F."

Type Locality: Magellan Straits, in 369 fathoms, mud. Type No. 96,243 U. S. Nat. Mus.

Range: Known only from the type locality.

Shell small, inequilateral, with blackish-brown or dark olivaceous periostracum; irregularly concentrically striated and sometimes very minutely radiately striated but not visibly reticulate; hinge with 15-17 anterior and 7 posterior teeth; margins of valves entire. Length, 15 mm.; height, 10.5 mm.; maximum diameter, 7.5 mm.

Nucula pisum Sowerby.

Nucula pisum Sowerby, *Proc. Zool. Soc. London,* 1832 (issued March 13, 1833), p. 198. "*Hab.* ad Valparaiso." "Dredged in coarse sand and gravel, at various depths from seven to forty fathoms." ———Sowerby, Conch. Illustr., *Nuculae,* 1833, p. 6, pl. 16, fig. 23. Valparaiso. ———Hanley, Cat. Rec. Biv. Shells, p. 172, 1843, p. 376, 1856?, Suppl. 20, fig. 12, 1856. Valparaiso. ———Hupé, Hist. de Chile, Zool., Vol. 8, 1854, p. 304. Valparaiso, etc. ———Hanley, Thes. Conch., Vol. 3, *Nuculidae,* 1860, p. 153, pl. 229 (*Nuculidae,* pl. 4), fig. 133. Valparaiso, Chile. ———Philippi, Los Fos. Terc. i. Cuart. Chile, 1887, p. 190, pl. 41, fig. 25. Recent on coast of Chile, also "fósil en la hacienda de La Cueva." ——— Dall, *Proc. U. S. Nat. Mus.,* Vol. 37, 1909, p. 250. Valparaiso to San Blas, Chile.

Type Locality: Valparaiso, Chile, in 7 to 40 fathoms, sand and gravel.

Range: Valparaiso to San Blas, Chile.

Reference to the illustration of *Nucula pisum* given in Reeve's[39] Conchologia Iconica has been omitted by us from the synonymy of this species because von Ihering[40], stated that the illustration is definitely that of *N. semiornata* d'Orbigny, an Atlantic species.

Nucula savatieri Mabille & Rochebrune.

Nucula savatieri Mabille & Rochebrune, Miss. Sci. Cap Horn, Vol. 6, Zool., pt. 2, 1889, p. H 112, pl. 8, figs. 2a, 2b, 2c. "*Hab.* ———Canal du Beagle. Baie Orange." ———Dall, *Bull. Mus. Comp. Zool.,* Vol. 43, no. 6, October, 1908, p. 367, pl. 18, fig. 11. Gulf of Panama, in 322 fathoms; 24 miles off Aguja Point, Peru, in 1036 fathoms; on the west coast of Patagonia in 122 fathoms; Straits of Magellan, in 77 fathoms.

Type Locality: Beagle Canal and Orange Bay, Chile.

Range: Straits of Magellan, Patagonia, to the Gulf of Panama.

Shell compressed-ovate, very inequilateral, pale olive periostracum; valves with smooth entire margins; hinge with 24 anterior and 10 posterior teeth. Length, 14-21 mm.; height, 10-15 mm.; diameter, 5-8 mm.

Nucula taeniolata Dall.

Nucula taeniolata Dall, *Bull. Mus. Comp. Zool.,* Vol. 43, no. 6, October, 1908, p. 368, pl. 7, figs. 3 and 5. U. S. S. *Albatross,* station 3417, "off Acapulco, Mexico, in 493 fathoms, mud, bottom temperature 40.6° F." ———Heath, *Mem. Mus. Roy. d'Hist. Nat. Belg.,* Ser. 2, Fasc. 10, 1937, pp. 4, 6, 17, pl. 3, fig. 24 (Anatomy). Acapulco, Mexico, in 493 fathoms.

Type Locality: Off Acapulco, Mexico, in 493 fathoms, mud. Type No. 122,897 U. S. Nat. Mus.

Range: Known only from the type locality.

Shell elongate, almost rostrate, thin, polished, and with dark olive-colored periostracum, more or less minutely irregularly wrinkled with a few very faint almost microscopic irregularly distributed radial striae; margins of valves simple, smooth; hinge with 10 anterior and 6 posterior teeth. Length 17 mm.; height, 11 mm.; diameter, 6.5 mm.

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39 *Nucula pisum* Sowerby, Sowerby, Conch. Icon., Vol. 18, *Nucula,* October, 1870, sp. 24, pl. 4, fig. 24.

40 von Ihering, H., *An. Mus. Nac. Buenos Aires,* Ser. 3, Vol. 7, 1907, p. 227.

Nucula tanneri Dall.

Nucula tanneri Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 367. "Straits of Magellan at station 2780, in 369 fathoms, mud, bottom temperature 47°F." Also on the west coast of Patagonia, in 61 to 348 fathoms, mud, temperature 48° to 54°.

Type Locality: Straits of Magellan, in 369 fathoms, mud. Type No. 96,243 U. S. Nat. Mus.

Range: Straits of Magellan and west coast of Patagonia.

Shell oval, inequilateral, brownish periostracum with concentric zones of darker and lighter shade; sculpture of faint concentric ripples; margins smooth; hinge with 14-17 anterior and 7-9 posterior teeth. Length, 22.5 mm.; height, 16.5 mm.; diameter, 10.0 mm.

Genus **Acila** H. & A. Adams.

Acila H. & A. Adams, Gen. Rec. Moll., Vol. 2, January, 1858, p. 545. ——— Stoliczka, *Mem. Geol. Surv. India, Palaeont. Indica*, Cret. Fauna South India, Vol. 3, 1871, p. 325. "*N. divaricata*, Hinds, is the type." ———Schenck, *Geol. Soc. America, Spec. Publ.* No. 4, 1936. See especially pp. 7-44.

Type (designated by Stoliczka): *Nucula divaricata* Hinds. [*Proc. Zool. Soc. London*, 1843, p. 97. China Sea; from eighty-four fathoms. ———Hinds, Zool. Voy. Sulphur, Moll. pt. 3, 1844 [January, 1845 on cover of pt. 3], p. 62, pl. 18, fig. 4. "Inhab. China Sea. From eighty-four fathoms." ———Sowerby, Conch. Icon., Vol. 18, *Nucula*, October, 1870, sp. 29, pl. 4, fig. 29. "*Hab.* Chinese Seas." ———Schenck, *Geol. Soc. America, Spec. Publ.* No. 4, 1936, p. 90, pl. 15, figs. 1-10; text fig. 8 (1, 2). Earlier records cited].

The species of the genus *Acila* are characterized by the presence of divaricate sculpture on the shell.

A recent monograph by Schenck[41] of the members of this group should be consulted for information regarding the species of *Acila*. The genus is known from Cretaceous to Recent.

Subgenus **Truncacila** Schenck in Grant & Gale.

Truncacila Schenck in Grant & Gale, *Mem. San Diego Soc. Nat. Hist.*, Vol. 1, November 3, 1931, p. 115. Type: *Nucula castrensis* Hinds. ———Schenck, *Geol. Soc. Amer., Special Publ.* No. 4, July 18, 1936, p. 23. Type: *Nucula castrensis* Hinds.

Type (by original designation): *Nucula castrensis* Hinds.

Shell without the shallow sinus characteristic of the typical section of *Acila*, the posterior end being truncated, as a rule, nearly at right angles (Grant & Gale).

Acila (Truncacila) castrensis Hinds.

Nucula castrensis Hinds, *Proc. Zool. Soc. London*, 1843, p. 98. "*Hab.* Sitka, Northwest America. A single specimen was dredged in the harbour, from seven fathoms, sand." ———Hinds, Zool. Voy. Sulphur, Moll., Pt. 3, 1844 [Jan. 1845 on cover of Pt. 3], p. 63, pl. 18, fig. 5. "Inhab. Sitka, North-west America. A single specimen was dredged in the harbour, from seven fathoms, sand." ———Sowerby, Conch. Icon., Vol. 18, *Nucula*, October, 1870, sp. 32, pl. 4, fig. 32. "*Hab.* North-West America."

Nucula lyalli Baird, *Proc. Zool. Soc. London*, 1863, p. 71. "*Hab.* Esquimalt Harbour, Vancouver Island; dredged by Dr. Lyall ..... in 8 to 10 fathoms."

Acila castrensis Hinds, Ashley, *Proc. Calif. Acad. Sci.*, Ser. 2, Vol. 5, 1895, pp. 327, 344. Purisima and Tunitas Creek, San Mateo County, California, Pliocene.

[41] Schenck, H. G. Nuculid Bivalves of the genus *Acila*. *Geol. Soc. America, Special Publ.* No. 4, July, 1936, 149 pp., 18 pls.

Also Miocene to Recent. ———Frizzell, *Nautilus*, Vol. 44, no. 2, 1930, pp. 50-53. Friday Harbor, Puget Sound, Washington, Recent. ———Haas, Dr. H. G. Bronns Klassen u. Ordnung des Tierreichs, Moll., Bivalvia, Bd. 3, Lief. 4, 1933, pp. 529-531, fig. 258.

Nucula (*Acila*) *castrensis* Hinds, I. S. Oldroyd, *Stanford Univ. Publ. Univ. Ser. Geol. Sci.*, Vol. 1, no. 1, 1924, p. 14, pl. 5, fig. 11; pl. 37, figs. 1, 2. Bering Sea to San Diego, California, also Miocene, Pliocene and Pleistocene. ———Grant & Gale, *Mem. San Diego Soc. Nat. Hist.*, Vol. 1, 1931, p. 116, pl. 1, figs. 6a, 6b. Earlier records cited. Miocene to Recent.

Acila (*Truncacila*) *castrensis* Hinds, Schenck, *Geol. Soc. America, Special Publ.* No. 4, 1936, p. 96, pl. 10, figs. 1-15; pl. 14, figs. 2, 3; text figure 7 (2-5). Pliocene to Recent. Earlier records cited with discussion of the species.

Type Locality: Sitka, Alaska, dredged in harbor in 7 fathoms.

Range: Sitka, Alaska, to Cedros Island, Lower California, 40 to 262 fathoms.

Collecting Station: Mexico: East of Cedros Island (126-D-10). 60 fathoms, crushed shell and eel grass bottom.

A single valve of *Acila castrensis* was dredged about 1¼ miles east of Cedros Island. This is a southern extension in the range of the species. Heath[42] has recently discussed the soft parts of *A. castrensis* and Schenck has discussed the species in detail in his work on *Acila*.

Family Nuculanidae.

The shells of the Nuculanidae are somewhat similar to those of the Nuculidae but the posterior end is elongate and rostrate; the ends of the shell are sometimes partly gaping; a ligament is present, often behind the beaks; the interior of the shell is porcellanous or sub-nacreous; the pallial line is sinuate due to the presence of siphons.

Most of the species of the Nuculanidae dwell in muddy portions of the bottom of the sea.

No representatives of *Yoldia, Cyrilla, Malletia* or of *Tindaria* are present in the collections made by Crocker and Beebe from west American waters. This may be explained in part by the fact that most of the species of such genera as *Yoldia* and *Tindaria* in the region covered by these expeditions occur at depths considerably greater than those from which most of the collections were secured.

Key to the Genera of Nuculanidae.

A. No lateral teeth on hinge
  a. Ligament internal ..... *Nuculana*
  aa. Ligament external
    b. Shell pointed posteriorly
      c. Shell veneriform, thickened ..... *Tindaria*
      cc. Shell elongate
        d. Shell lanceolate, length more than double width *Adrana*
        dd. Shell broader, length about one third greater than width ..... *Yoldia*
    bb. Shell rounded posteriorly ..... *Malletia*

B. A well developed lateral tooth in right valve with corresponding depression in left; shell very small ..... *Cyrilla*

[42] Heath, H. *Mem. Mus. Roy. d'Hist. Nat. Belg.*, Ser. 2, Fasc. 10, 1937, pp. 4, 9, etc. pl. 4, figs 30, 36; pl. 6, fig. 50; pl. 9, figs. 76, 77. See also Hilton, W. A., *Jour. Entomol. & Zool.*, Vol. 11, no. 4, 1919, p. 77, figs. 1-7. Monterey Bay, California, in 60-80 fathoms, and south of Alaskan Peninsula, in 483 fathoms.

Genus **Nuculana** Link.

Nuculana Link, Beschreib. Nat.-Samml. Univ. Rostock, Abt. 3, May 17, 1807, p. 155. Sole species: "*N. rostrata*" [Chemnitz]. ———Grant & Gale, *Mem. San Diego Soc. Nat. Hist.*, Vol. 1, 1931, p. 118. Type: *Arca rostrata* Chemnitz.

Leda Schumacher, Essai Nouv. Syst. Test., 1817, pp. 55, 172, 173. Type: *Arca rostrata* Chemnitz. Illustrated by Schumacher on pl. 19, fig. 4.

Type (by monotypy): *Arca rostrata* Chemnitz. [Neues Syst. Conchyl.-Cab., Bd. 7, 1784, p. 206, pl. 55, figs. 550, 551. Recent, northern coasts of Europe. ———Montagu, Suppl. Test. Brit., 1808, p. 55, pl. 27, fig. 7. Norwegian and Baltic Seas, also Scotland].

The genus *Nuculana* and closely related forms originated in the Paleozoic. *Praeleda* Pfab[43] has been described from the Silurian of Bohemia and has been recorded from the Ordovician of Belgium. The genus *Nuculana* is widely distributed but the majority of the species occur on muddy bottoms in cold water. Verrill & Bush[44] published a revision of the genera of the Nuculanidae of the Atlantic coast of the United States. Stewart[45] has discussed some of the superspecific groups in the Nuculanidae as has Iredale[46] and Prashad[47].

Key to the Species of *Nuculana*.

A. Umbos distinctly anterior
- a. Surface smooth or with very feeble sculpture
  - b. Hinge with 15 anterior and 22 posterior teeth ..... *loshka*
  - bb. Hinge with 15 anterior and 38 posterior teeth ..... *peruviana*
- aa. Surface with distinct concentric sculpture
  - c. Umbos at about the anterior fourth
    - d. Posterior dorsal margin nearly straight ..... *hamata*
    - dd. Posterior dorsal margin strongly concave ..... *cordyla*
  - cc. Umbos at about the anterior third
    - e. Anterior end with a distinct radiating ray or shallow groove
      - f. Size small, length about 6 mm. ..... *acuta*
      - ff. Size large, length about 20 mm. or more
        - g. Concentric sculpture fine, weak ..... *marella*
        - gg. Concentric sculpture strong, distant riblets ..... *costellata*
    - ee. Anterior end without a radiating ray or groove or if present, very weak

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43 *Praeleda* Pfab, *Palaeontogr.*, Bd. 80, Abt. A, Lief. 4-6, April, 1934, p. 231. "Typus des genus: *P. compar* (Barr.)."

44 Verrill, A. E., & Bush, H. J. Revision of the genera of Ledidae and Nuculidae of the Atlantic Coast of the United States. *Amer. Jour. Sci.*, Ser. 4, Vol. 3, 1897, pp. 51-63, 22 figs. in text. ——— *Proc. U. S. Nat. Mus.*, Vol. 20, 1898, pp. 775-901.

Yonge (*Phil. Trans. Roy. Soc. London*, Ser. B, Biol. Sci., No. 566, Vol. 230, August 9, 1939, pp. 79-147, 1 pl., 39 figs. in text) has discussed the anatomy of the protobranchiate mollusks.

45 Stewart, R. B., *Acad. Nat. Sci. Philadelphia, Spec. Publ.* No. 3, 1930, pp. 48-64.

46 Iredale, T., *Rec. Austral. Mus.*, Vol. 17, no. 4, 1929, pp. 158-159. ———Brit. Mus. (Nat. Hist.) Great Barrier Reef Exped. 1928-29. Sci. Repts. Vol. 5, no. 6, Moll. Pt. 1, 1939, pp. 238-241. In this paper three new genera of Nuculanidae are proposed. *Eptoleda*, "Type: *Leda darwini* Smith"; *Zygonoleda*, "Type: *Z. corbuloides minutalis* subsp. nov."; *Tepidoleda*, "Type: *T. lata orion* subsp. nov."

Powell (*Proc. Malacol. Soc. London*, Vol. 21, pt. 4, March, 1935, pp. 252-255, pl. 27), has described some Recent and Tertiary Nuculanidae from New Zealand.

47 Prashad, B., Siboga Exped., Vol. 53c, Lamell., 1932, pp. 18-19.

h. Anterior end without radiating ray or groove
  i. Without deeply impressed lines near base..*calcar*
  ii. With 6 to 8 impressed lines near base, not coincident with lines of growth.....*calcarella*
hh. Anterior end with a very weak radiating ray or groove .....*cuneata*

B. Umbos central or subcentral
  a. Sculpture faint or obsolete over most of the shell
    b. Striae obsolete on central portion of shell; no radials
      c. Size large, conspicuous oblique striae posteriorly, length about 35 mm. ..... *polita*
      cc. Size smaller, no oblique posterior striae, length about 15 mm. ..... *pontonia*
    bb. Striae present on basal margin, radially rippled.....*acrita*
  aa. Sculpture strong, continuous, concentric
    d. Posterior dorsal area defined by two ridges or angles
      e. Anterior end with a radial ray or groove
        f. Concentric ridges evenly spaced
          g. Radiating lyrae well developed
            h. Radiating lyrae over entire shell.....*hindsii*
            hh. Radiating lyrae confined to posterior end.... *crispa*
          gg. Radiating lyrae, if present, very fine, confined to the umbonal region
            i. Anterior groove shallow, barely discernible.. *eburnea*
            ii. Anterior groove very conspicuous.....*ornata*
        ff. Concentric ridges not evenly spaced
          j. Ridges widely spaced toward umbos, close toward margin .....*impar*
          jj. Ridges irregularly spaced.....*clenensis*
      ee. Anterior end without a radial ray or groove
        k. Posterior end obtuse (60°), shell thin, fragile....*agapea*
        kk. Posterior end acute, shell solid.....*bicostata*
    dd. Posterior dorsal area with not more than one ridge or angle
      l. size small, length less than 25 mm.
        m. Dorsal area defined by one ridge, posterior end attenuated.
          n. Concentric sculpture extending at least to posterior dorsal ridge
            o. Size about 15 to 20 mm.
              p. Anterior hinge teeth 26, posterior 20 ... *callimene*
              pp. Anterior hinge teeth 12, posterior 12 *taphria*
            oo. Size smaller, length 10 mm. or less
              q. Length about 10 mm.....*excavata*
              qq. Length about 5 mm.....*oxia*
          nn. Shell smooth, at least in front of posterior dorsal ridge *laeviradius*

KEY TO THE SPECIES OF *Nuculana* (continued):

mm. Posterior dorsal area without ridge or angle, both ends rounded
  r. Anterior end without a radiating ray or groove
    s. Posterior end attenuated but not acute ..... *rhytida*
    ss. Both ends evenly rounded ..... *lobula*
  rr. Anterior end with a radiating ray or groove ..... *lucasana*
ll. Size large, shell heavy, length over 30 mm. ..... *gibbosa*

Subgenus **Saccella** Woodring.

Ledina Sacco, Moll. Terr. Terz. Piemonte e Liguria, Pt. 26, December, 1898, p. 53. "(tipo *L. fragilis* (Chemnitz.))."

Not *Ledina* Dall, *Trans. Wagner Free Inst. Science*, Vol. 3, pt. 4, April, 1898, p. 580. Type: *Leda eborea* Conrad, 1860 (not *L. eborea* Conrad, 1846) =*L. smirna* Dall, Eocene of Gulf States of United States.

Saccella Woodring, *Carnegie Inst. Washington, Publ.* No. 366, May 20, 1925, p. 15. Type: *Arca fragilis* Chemnitz (=*Leda commutata* Philippi). New name for *Ledina* Sacco not *Ledina* Dall.

Type (by original designation): *Arca fragilis* Chemnitz. [Neues Syst. Conchyl.-Cab., Bd. 7, 1784, p. 199, pl. 55, fig. 546. "Mittelländischen Meeres." ———Bucquoy, Dautzenberg & Dollfus, Moll. Mar. Roussillon, Vol. 2, Fasc. 5 (Pelecypoda, Fasc. 18), 1891, p. 215, pl. 37, figs. 26, 27, 28, 29, 30, 31. Mediterranean, and Atlantic Ocean. (=*Leda commutata* Philippi). Miocene to Recent in the Mediterranean region.].

Saccella resembles *Lembulus*[48] but the former has concentric instead of diagonal sculpture and has a narrower and shallower posterior groove. *Saccella* occurs Recent and fossil in Europe, eastern and western North and Central America and elsewhere. It has been recorded fossil in the Eocene of California[49] and Tertiary of New Zealand[50].

Nuculana (Saccella) acuta Conrad.

Plate I, Figure 11.

Nucula acuta Conrad, Amer. Mar. Conch., 1832, p. 32, pl. 6, fig. 3. North Carolina; Recent.

Leda acuta Conrad, Verrill, *Trans. Connecticut Acad. Arts and Sci.*, Vol. 6, 1884, p. 259, pl. 30, fig. 15. New England Coast. ———Dall, *Bull. Mus. Comp. Zool.*, Vol. 12, no. 5, 1886, p. 251, pl. 7, figs. 3a, 3b, 8 [Not all the synonymy]. New England; Florida; Jamaica. ———Dall, *Trans. Wagner Free Inst. Sci.*, Vol. 3, pt. 4, 1898, p. 592. Oligocene to Recent on Atlantic Coast. Also Recent on Pacific Coast of California. ———Dall & Simpson, *Bull. U. S. Fish Comm.*, Vol. 20, pt. 1, for 1900 (issued separately November 29, 1901), p. 458. Mayaguez Harbor, Porto Rico. ———Dall, *Proc. U. S. Nat. Mus.*, Vol. 37, 1909, p. 250. California, the Gulf of Panama, and south to Valparaiso, Chile. Also Atlantic. ———Gardner, *U. S. Geol. Surv., Prof. Paper* 142-A, 1926, p. 12, pl. 2, figs. 13-16. Eastern North America; Miocene to Recent.

[48] *Lembulus* Risso, Hist. Nat. l'Europ. Merid., Vol. 4, 1826, p. 319. Type (designated by Gray, 1847): *Lembulus rossianus* Risso (=*Arca pella* Linnaeus). Recent, Mediterranean Sea. Illustrated by Risso, 1826, pl. 11, fig. 166, and by Bucquoy, Dautzenberg & Dollfus, Moll. Mar. Roussillon, Vol. 2, Fasc. 5 (Pelecypoda, Fasc. 18), 1891, p. 218, pl. 37, figs. 32, 33, 34, 35. Mediterranean; Adriatic; Atlantic Ocean.

[49] Vokes, H. E., *Ann. New York Acad. Sci.*, Vol. 38, 1939, pp. 41-43.

[50] See *Nuculana (Saccella) duplicarina* Laws, *Trans. and Proc. Roy. Soc. New Zealand*, Vol. 68, pt. 4, March, 1939, p. 468, pl. 62, fig. 2. Pakaurangi Point, Kaipara Harbor, New Zealand. Tertiary. ———See also, Marwick, *Geol. Surv. New Zealand, Palaeo. Bull.* No. 13, 1931, pp. 50, 51.

Nuculana acuta Conrad, M. Smith, East Coast Mar. Shells (Edwards Bros., Ann Arbor, Michigan), 1937, p. 26, pl. 2, fig. 2. Off Martha's Vineyard to the West Indies.

Type Locality: North Carolina.

Range: Off Martha's Vineyard, Massachusetts, to the West Indies.

Nuculana acuta has been recorded from various localities on the west coast ranging from Alaska to Chile. Dall in 1909 cited the range as from California south to Chile. In a later work[51] he cited it as occurring from Nazan Bay, Atka Island, Aleutian Islands, Alaska, to the Gulf of California. The species is well known on the Atlantic coast from Massachusetts to the West Indies, but its occurrence in Western America can be considered very doubtful until definitely proved.

Nuculana (Saccella) callimene Dall.

Plate I, Figure 13.

Leda (*Jupiteria*) *callimene* Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 372, pl. 17, figs. 3 and 4. "U. S. S. 'Albatross,' Station 3396, Gulf of Panama, 259 fathoms, mud, bottom temperature 47.4° F." Also at Tomé, Chile, in 14 fathoms.

Leda callimene Dall, Dall, *Proc. U. S. Nat. Mus.*, Vol. 37, 1909, p. 250. Gulf of Panama to Tomé, Chile. ———Zetek, *Rev. Nueva*, Nos. 1 & 2, 1918, p. 37. Panama.

Type Locality: Gulf of Panama, in 259 fathoms, mud. The type is No. 122,910 U. S. Nat. Mus.

Range: Gulf of Nicoya to Tomé, Chile.

Collecting Station: Costa Rica: 3 miles south of Blanco Island, Gulf of Nicoya. 100 fathoms.

A single specimen of *Nuculana callimene* was dredged in the Gulf of Nicoya. Compared to *N. taphria* Dall it is more elongate, less inflated, and the exterior surface is less polished.

Specimens somewhat similar to *Nuculana callimene* have been recorded by E. K. Jordan[52] from the Pleistocene of Magdalena Bay, Lower California.

Nuculana (Saccella) elenensis Sowerby.

Plate I, Figures 12, 14, 15, 16, 17, 18, 19, 22.

Nucula elenensis Sowerby, *Proc. Zool. Soc. London*, 1832 (issued March 13, 1833), p. 198. "*Hab.* ad Sanctam Elenam." "Dredged in sandy mud at a depth of six fathoms." Recent. ———Sowerby, Conch. Illustr., *Nuculae*, 1833, p. 4, pl. 15, fig. 14. "St. Elena, Mr. Cuming." ———Müller, Synop. Test. Viv., 1836, p. 191. Type locality cited. ———Reeve, Conch. Syst., Vol. 1, 1841, p. 111, pl. 85, fig. 14. ———Hanley, Cat. Rec. Bivalve Shells, 1843, p. 169, Suppl. pl. 19, fig. 56, 1846. "W. Colombia." ———C. B. Adams, *Ann. Lyceum Nat. Hist. New York*, Vol. 5, 1852, p. 478. Panama. Also earlier records cited.

Leda ?elenensis Sowerby, Carpenter, Cat. Mazatlan Shells, February, 1856, p. 145. Mazatlan, Mexico. Also earlier records cited.

Leda elenensis Sowerby, d'Orbigny, Voy. Amér. Mérid., Vol. 5, 1846, p. 545. Santa Elena, Ecuador. ———Hanley, Thes. Conch., Vol. 3, 1860, *Leda*, p. 121, pl. 228, [*Nuculidae*, pl. 3], figs. 70, 71, 72. Panama. ———Sowerby, Conch. Icon., Vol. 18, *Laeda*, September, 1871, sp. 32, pl. 6, figs. 32a, 32b. "*Hab.* St. Elena.

[51] Dall, W. H., *U. S. Nat. Mus., Bull.* 112, 1921, p. 10.

[52] *Leda* sp. aff. *callimene* Dall (young), E. K. Jordan, *Bull. South. Calif. Acad. Sci.*, Vol. 23, pt. 5, September-October (issued October 25), 1924, p. 148. Quaternary at Magdalena Bay, Lower California. ———E. K. Jordan, *Contrib. Dept. Geol. Stanford Univ.*, Vol. 1, no. 4, 1936, p. 112. Previous record cited.

Panama." ———Dall, *Proc. U. S. Nat. Mus.*, Vol. 37, 1909, p. 251. Santa Elena, Ecuador. ———Olsson, *Nautilus*, Vol. 37, no. 4, 1924, p. 126. Salinas, Ecuador.

Leda elenensis Sowerby var. *gibbosa* Hanley, Thes. Conch., Vol. 3, 1860, p. 121.

Leda elenensis Sowerby var. *media* Hanley, Thes. Conch., Vol. 3, 1860, p. 121.

Leda elenensis Sowerby var.? *pyriformis* Hanley, Thes. Conch., Vol. 3, 1860, p. 121.

Leda (*Jupiteria*) *elenensis* Sowerby, Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, p. 374, October, 1908. In 52 fathoms in Panama Bay.

Leda (*Saccella*) *acapulcensis* Pilsbry & Lowe, *Proc. Acad. Nat. Sci. Philadelphia*, Vol. 84, May 21, 1932, p. 107, pl. 17, figs. 1 and 2. "Mexico: Acapulco, 20 fathoms."

Nuculana acapulcensis Pilsbry & Lowe, Strong, Hanna & Hertlein, *Proc. Calif. Acad. Sci.*, Ser. 4, Vol. 21, no. 10, December 21, 1933, p. 118. Acapulco, Mexico.

Nuculana elenensis Sowerby, Hertlein, *Bull. South. Calif. Acad. Sci.*, Vol. 33, pt. 2, May-August (issued August 31), 1934, p. 65. San Ignacio Lagoon, Lower California; Pleistocene. ———E. K. Jordan, *Contrib. Dept. Geol. Stanford Univ.*, Vol. 1, no. 4, 1936, pp. 112, 118. Magdalena Bay, Lower California; Pleistocene. Recent, Panama and Santa Elena, Ecuador.

Nuculana elenense Sowerby, Strong & Hertlein, *Allan Hancock Pacific Exped.* (*Univ. South. Calif.*), Vol. 2, no. 12, 1939, p. 183. Bahia Honda, Veragua, Panama; off Taboga Island, Panama.

Type Locality: Santa Elena, Ecuador, in 6 fathoms, sandy mud.

Range: Santa Inez Bay, Lower California, to Salinas, Ecuador.

Collecting Stations: Mexico: Arena Bank, Gulf of California (136-D-13,-18). 40-45 fathoms, mud and *Arca* conglomerate bottom; Santa Inez Bay, Gulf of California (144-D-2). 2½ fathoms, sand, weed and rock bottom; also (145-D-1,-3, and shore). 4-13 fathoms, sand bottom; Tenacatita Bay (183-D-3). 40 fathoms, sandy mud bottom; Manzanillo (184-D-2). 30 fathoms, gravelly sand bottom; Acapulco (189-D-3). 13 fathoms, mud bottom; 4 miles south-southwest of Maldanado Point (192-D-3). 38 fathoms, mud bottom; Port Guatulco (195-D-19). 17 fathoms, gray mud and crushed shell bottom; Tangola-Tangola Bay (196-D-17). 23 fathoms, mud bottom; Costa Rica: Port Parker (203-D-1,-3). 12-15 fathoms, shelly mud bottom.

Nuculana elenensis Sowerby is a very variable species and as pointed out by Jordan neither the form nor sculpture is constant in a series. Sowerby gave the varietal names, *gibbosa, media* and *pyriformis*, to forms of this species. With a very large series of shells from many localities we can find no constant distinguishing feature for separation of Pilsbry & Lowe's species *acapulcensis*. They compared it with *Leda agapea* Dall which we have not seen. The specimens here referred to *elenensis* have a strong groove on the anterior end. This is not shown on the figures of *acapulcensis* Pilsbry & Lowe. We have studied a series of several hundred specimens from Sta. 203-D-3. These agree well with Hanley's figure 71 (Thes. Conch., Vol. 3, pl. 228, *Nuculidae*, pl. 3). Almost none of our specimens show the nearly smooth area near the ventral margin as shown by Pilsbry & Lowe on their pl. 17, fig. 1. One specimen in the collection shows a tendency toward this type of sculpture and in many of the larger specimens there is a definite line beyond which the sculpture is somewhat finer.

Nuculana bicostata Sowerby appears to be distinguished by the presence of two pronounced rostral ribs while there is but one rib on the posterior part of *N. elenensis*. *Nuculana acuta* Conrad is more truncate posteriorly and is more compressed than *N. elenensis*. The shorter and more contracted posterior portion of the shell serves to separate *N. elenensis* from young specimens of *N. peruviana* Dall from Peru.

Nuculana (Saccella) eburnea Sowerby.

Plate II, Figures 1, 2, 3.

Nucula eburnea Sowerby, *Proc. Zool. Soc. London*, 1832 (issued March 13, 1833), p. 198. "*Hab.* ad oras Columbiae Occidentalis." "Found in sandy mud, at a depth of from seven to nine fathoms, in the Bay of Caraccas." ———Sowerby, Conch. Illustra., *Nuculae*, 1833, pp. 4, 6, pl. 15, fig. 10. Bay of Caraccas. ———Müller, Synop. Test. Viv., 1836, p. 191. Type locality cited. ———Reeve, Conch. Syst., Vol. 1, 1841, p. 111, pl. 85, fig. 10. ———Catlow, Conch. Nomencl., 1845, p. 53. ———Hanley, Cat. Rec. Bivalve Shells, p. 169, 1843, 376, ?1856, Suppl. pl. 19, fig. 57, 1846. W. Colombia.

Leda eburnea Sowerby, d'Orbigny, Voy. Amér. Mérid., Vol. 5, 1846, p. 546. "M. Cuming l'a découverte dans la baie de Caracas, sur la côte occidentale de la république de la Équateur." ———Carpenter, *Rept. Brit. Assoc. Adv. Sci.* for 1863 (issued 1864), p. 560. Reprint in *Smithson. Misc. Coll.*, No. 252, 1872, p. 46. Panama; Bay of Caraccas. ———Hanley, Thes. Conch., Vol. 3, 1860, p. 124, pl. 228 (*Nuculidae*, pl. 3), fig. 90. Panama; Bay of Caraccas. ———Sowerby, Conch. Icon., Vol. 18, *Laeda*, September, 1871, pl. 5, fig. 29. "*Hab.* Bay of Panama." ———Dall, *Proc. U. S. Nat. Mus.*, Vol. 37, 1909, p. 250. "Gulf of Panama to the Bay of Caraques, Ecuador." ———Zetek, *Rev. Nueva*, Nos. 1 & 2, 1918, p. 37. Panama.

Nucula lyrata Hinds, *Proc. Zool. Soc. London*, 1843, p. 100. "*Hab.* Panama; from thirty fathoms." ———Hinds, Zool. Voy. Sulphur, 1844 (January, 1845 on the cover of Moll., Pt. 3), p. 64, pl. 18, fig. 12. Original locality cited.

Type Locality: Bay of Caraccas, Ecuador, in 7 to 9 fathoms, sandy mud.

Range: Meanguera Island, Gulf of Fonseca, El Salvador, to Bay of Caraccas, Ecuador.

Collecting Stations: El Salvador: Meanguera Island, Gulf of Fonseca (199-D-1). 16 fathoms, sandy mud and crushed shell bottom; Nicaragua: Corinto (200-D-19). 12-13 fathoms, mangrove leaves on bottom; Costa Rica: 14 miles southeast of Judas Point (214-D-1 to 4). 42-61 fathoms, mud, shell and rocky bottom.

The shell of *Nuculana eburnea* Sowerby has a smooth or appressed area anterior to the posterior keel somewhat resembling *N. laeviradius* Pilsbry & Lowe. It differs from that species in the great size, more acuminate posterior end and in lacking the elevated ridge on the anterior end which runs from the beaks to the anterior ventral margin on *N. laeviradius*. Specimens of *N. eburnea* in the present collection average about 12.6 mm. in length. *Nuculana lyrata* Hinds, originally described from Panama, was considered to be a synonym of *N. eburnea* by Hanley and Carpenter. From an inspection of the figure given by Hinds it appears likely that *N. lyrata* can be considered synonymous with *N. eburnea*.

Nuculana (Saccella) gibbosa Sowerby.

Plate II, Figures 5, 8.

Nucula gibbosa Sowerby, *Proc. Zool. Soc. London*, 1832 (issued March 13, 1833), p. 198. "*Hab.* ad littora Peruviae." "Found in soft mud, at a depth of five fathoms, at Tumbez in Peru." "A variety, with a less elevated ridge in the centre of the anterior dorsal margin, and of much smaller size, was found in mud, at twelve fathoms, in the Gulf of Nocoiyo." ———Sowerby, Conch. Illustr., *Nuculae*, 1833, p. 4, pl. 15, fig. 9. "Gulf of Nocoiyo. Mr. Cuming." ———Deshayes, ed. of Lamarck's Anim. s. Vert., Vol. 6, 1835, p. 508. (as *Nucula gibossa*. Cuming, but in index it is cited as *Nucula gibbosa*). "Habite les mers du Pérou, près des rivages." ———Müller, Syn. Test. Viv., 1836, p. 191. Original locality cited. ———Reeve, Conch. Syst., Vol. 1, 1841, p. 111, pl. 85, fig. 9. ———Hanley, Cat. Rec. Bivalve Shells, p. 169, 1843, p. 376, ?1856, Suppl. pl. 19, fig. 55, 1846. Peru.

Leda gibbosa Sowerby, d'Orbigny, Voy. Amér. Mérid., Vol. 5, 1846, p. 545. "Côte de Payta (Pérou)." ———Hanley, Thes. Conch., Vol. 3, *Nuculidae*, 1860, p. 120, pl. 228 (*Nuculidae*, pl. 3), fig. 79. Peru. ———Sowerby, Conch. Icon., Vol. 18, *Laeda*, November, 1871, sp. 51, pl. 8, fig. 51. "*Hab.* Peru." ———Dall, *Proc. U. S. Nat. Mus.*, Vol. 37, 1909, p. 251. Gulf of Panama to Paita, Peru. ———Zetek, *Rev. Nueva*, Nos. 1 & 2, 1918, p. 37. Panama. ———Strong, Hanna & Hertlein, *Proc. Calif. Acad. Sci.*, Ser. 4, Vol. 21, no. 10, 1933, p. 118. Acapulco, Mexico.

Leda (*Jupiteria*) *gibbosa* Sowerby, Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, 1908, p. 372. Panama Bay in 26 to 47 fathoms, mud.

Nuculana gibbosa Tomlin, *Jour. Conch.*, Vol. 18, no. 7, 1928, p. 189. Coiba Island, Panama, in 10 fathoms. Gorgona Island, Colombia, in 20 fathoms.

Type Locality: Tumbez, Peru, in 5 fathoms, soft mud.

Range: Acapulco, Mexico, to Tumbez, Peru.

Collecting Stations: Mexico: Tangola-Tangola Bay (196-D-19). 30 fathoms, mud bottom; Costa Rica: off Ballena Bay, Gulf of Nicoya (213-D-11-17). 35-45 fathoms, mud bottom.

This is a thick, elongate, posteriorly pointed shell with fairly gibbous beaks. It is ornamented by strong concentric somewhat upturned ribs which are separated by smooth bottomed grooves.

Nuculana (Saccella) impar Pilsbry & Lowe.

Plate II, Figure 6.

Leda impar Pilsbry & Lowe, *Proc. Acad. Nat. Sci. Philadelphia*, Vol. 84, May 21, 1932, p. 106, pl. 17, figs. 3, 4, 5, 6. "Mexico: Guaymas, 20 fathoms." ———Hertlein, *Bull. South. Calif. Acad. Sci.*, Vol. 33 pt. 2, May-August (issued August 31), 1934, p. 62. Maria Magdalena Island, Tres Marias Islands; Pleistocene. ———Lowe, *Trans. San Diego Soc. Nat. Hist.*, Vol. 8, no. 6, 1935, p. 27. Punta Penasco, Sonora, Mexico.

Type Locality: Guaymas, Mexico, in 20 fathoms. Type No. 155636 Acad. Nat. Sci. Philadelphia.

Range: Punta Penasco, Sonora, Mexico, to Port Parker, Costa Rica.

Collecting Stations: Mexico: Santa Inez Bay, Gulf of California (145-D-1,-3). 4-13 fathoms, sand bottom; Costa Rica: Port Parker (203-D-3). 12 fathoms, shelly mud bottom.

The sculpture of this species is characteristic. This consists of concentric ridges, which are fine and close on the beaks, then widely spaced, then again becoming closer and about equal to their intervals from about the middle of the valves to the ventral margin.

Nuculana (Saccella) laeviradius Pilsbry & Lowe.

Plate II, Figures 4, 7.

Leda laeviradius Pilsbry & Lowe, *Proc. Acad. Nat. Sci. Philadelphia*, Vol. 84, May 21, 1932, p. 106, pl. 17, fig. 7. "Mexico: Guaymas, 20 fathoms."

Leda leviradius Pilsbry & Lowe, Lowe, *Trans. San Diego Soc. Nat. Hist.*, Vol. 8, no. 6, 1935, p. 27. Punta Penasco, Sonora, Mexico.

Type Locality: Guaymas, Mexico, in 20 fathoms. Type No. 155635 Acad. Nat. Sci. Philadelphia.

Range: Punta Penasco, Sonora, Mexico, to Port Parker, Costa Rica.

Collecting Stations: Mexico: Santa Inez Bay, Gulf of California (145-D-1,-3). 4-13 fathoms, sand bottom; Costa Rica: Port Parker (203-D-1,-3). 12-15 fathoms, sandy mud, crushed shell and shelly mud bottom.

The presence of a smooth band preceding the posterior ridge and the strong hinge in proportion to the size of the shell are characteristic features of this species. In some specimens a considerable portion of the exterior of the shell is smooth.

Nuculana (Saccella) taphria Dall.

Nucula caelata Hinds, *Proc. Zool. Soc. London*, December, 1843, p. 99. "*Hab.* California, between 38° 18′ and 34° 24′ north latitude; namely, at Russian Bodegas, San Francisco, and Santa Barbara, in from six to ten fathoms." "Cab. Belcher." ———Hinds, Zool. Voy. Sulphur, Moll., pt. 3, 1844 [January, 1845 on cover of pt. 3], p. 64, pl. 18, fig. 13. Original locality cited.

Not *Nucula coelata* Conrad, *Amer. Jour. Sci.*, Vol. 23, no. 2, January, 1833, p. 343. Claiborne, Alabama. London Clay. [Eocene].

Leda caelata Hinds, Hanley, Thes. Conch., Vol. 3, 1860, p. 129, pl. 228 (*Nuculidae*, pl. 3), figs. 95, 96. California. ———Sowerby, Conch. Icon., Vol. 18, *Laeda*, February, 1871, sp. 6, pl. 2, figs. 6a, 6b. "*Hab.* California."

Leda taphria Dall, *Nautilus*, Vol. 10, no. 6, Oct., 1896, p. 70. New name for *Nucula caelata* Hinds, not *Nucula caelata* Conrad, 1833. Claiborne, Eocene. ———Dall, *Nat. Hist. Soc. Brit. Columbia, Bull.* No. 2, January, 1897, p. 7 (in text), pl. 2, figs. 6 and 8. Bodega Bay, California to San Diego. ———Arnold, *Proc. U. S. Nat. Mus.*, Vol. 32, 1907, p. 544, pl. 48, figs. 5, 5a. Pliocene to Recent in the California Province. ———I. S. Oldroyd, *Stanford Univ. Publ. Univ. Ser. Geol. Sci.*, Vol. 1, no. 1, 1924, p. 16, pl. 37, figs. 7, 7a, 8. Bodega Bay, California to Lower California. Also Miocene to Recent in California.

Nuculana taphria Dall, Grant & Gale, *Mem. San Diego Soc. Nat. Hist.*, Vol. 1, 1931, p. 121, pl. 1, figs. 8 and 9. Earlier records cited. Miocene to Recent. ———Hertlein, *Bull. South. Calif. Acad. Sci.*, Vol. 33, pt. 2, May-August (issued August 31), 1934, p. 62. Maria Magdalena Island, Tres Marias Islands; Pleistocene. ———E. K. Jordan, *Contrib. Dept. Geol. Stanford Univ.*, Vol. 1, no. 4, 1936, p. 112. Magdalena Bay, Lower California (Dall); Pleistocene. ———Willett, *Trans. San Diego Soc. Nat. Hist.*, Vol. 8, no. 30, 1937, p. 386. About 2 miles NE. of Playa del Rey, Baldwin Hills, Los Angeles County, California; Upper Pleistocene.

Type Locality: Bodega Bay, California, in 6 to 10 fathoms.

Range: Bodega Bay, California, to Punta Arena, Lower California.

Collecting Stations: Mexico: East of Cedros Island (126-D-12). 45 fathoms, crushed shell and mud bottom; Arena Bank, Gulf of California (136-D-22). 45 fathoms, mud bottom.

The concentric sculpture on this species is uniform and prominent. The beaks are nearly central and the rostrum is rather bluntly pointed.

Heath[53] has studied the soft parts of this species.

Subgenus ***Politoleda*** Hertlein & Strong, nov.

Type: *Nucula polita* Sowerby.

Shell elongate, posteriorly pointed. Sculpture consists of very fine concentric lines of growth, and on the lower half of the shell fine wavy incised lines which on the whole posterior dorsal part of the shell are nearly parallel to the posterior dorsal margin.

Nuculana (Politoleda) polita Sowerby.

Plate II, Figure 9.

Nucula polita Sowerby, *Proc. Zool. Soc. London*, 1832 (issued March 13, 1833), p. 198. "*Hab.* ad Panamam." "A single specimen of this very beautiful species was dredged up in sand from a depth of seven fathoms." ———Sowerby,

[53] Heath, H., *Mem. Mus. Roy. d'Hist. Nat. Belgique*, Ser. 2, Fasc. 10, 1937, pp. 5, 6, etc., pl. 7, figs. 59, 60.

Conch. Illustr., *Nuculae*, March 8, 1833, p. 4, pl. 15, fig. 11. "Panama. Mr. Cuming." ———Deshayes, ed. of Lamarck's Anim. s. Vert., Vol. 6, 1835, p. 507. Panama. ———Hanley, Cat. Bivalve Shells, p. 169, 1843, Suppl. pl. 19, fig. 53, 1846. Panama. ———Müller, Syn. Test. Viv., 1836, p. 190. "Legit H. Cuming ad Panamam". ———Reeve, Conch. Syst., Vol. 1, 1841, p. 111, pl. 85, fig. 11.

Leda polita Sowerby, Hanley, Thes. Conch., Vol. 3, *Leda*, 1860, p. 125, pl. 228 (*Nuculidae*, pl. 3), fig. 68. Panama. ———Sowerby, Conch. Icon., Vol. 18, *Laeda*, September, 1871, sp. 16, pl. 3, fig. 16. "*Hab.* Panama." ———Zetek, *Rev. Nueva*, Nos. 1 & 2, 1918, p. 37. Panama. ———Pilsbry & Lowe, *Proc. Acad. Nat. Sci. Philadelphia*, Vol. 84, p. 141, 1932. On the beach at Old Panama.

Nuculana polita Sowerby, Strong & Hertlein, *Allan Hancock Pac. Exped.* (*Univ. South. Calif.*), Vol. 2, no. 12, 1939, p. 183. Beach near Panama Vieja (Old Panama).

Type Locality: Panama, in 7 fathoms, sand.

Range: Champerico, Guatemala, to Panama.

Collecting Stations: Guatemala: 7 miles west of Champerico (197-D-1-2). 14 fathoms, mud bottom; El Salvador: La Libertad (198-D-2). 14 fathoms, mud bottom; Meanguera Island, Gulf of Fonseca (199-D-1). 16 fathoms, sand, mud, and crushed shell bottom; Panama: Gulf of Chiriqui (221-D-1-5). 35-40 fathoms, sandy mud bottom.

The shell of *Nuculana polita* is oblong, anteriorly beaked, ornamented by subdued concentric striae and by oblique striae on the lower part and over the whole posterior portion of the shell. Young specimens 15 mm. in length lack the oblique striae. Specimens reach a length of 45 mm. *Nuculana guppyi* Dall[54] from the Miocene of Trinidad bears some similarity to *N. polita* but has a more attenuated shell and the beaks are more anterior.

Subgenus **Costelloleda** Hertlein & Strong, nov.

Type: *Nucula costellata* Sowerby.

Shell elongate and with strong concentric sculpture. *Costelloleda* is somewhat similar in general appearance to *Poroleda* Iredale[55] and *Thestyleda* Iredale.

Nuculana (Costelloleda) costellata Sowerby.

Plate II, Figure 10.

Nucula costellata Sowerby, *Proc. Zool. Soc. London*, 1832 (issued March 13, 1833), p. 198. "*Hab.* ad Panamam." "Two specimens were taken in sandy mud at a depth of ten fathoms." ———Sowerby, Conch. Illustr., *Nuculae*, 1833, p. 4, pl. 15, fig. 8. "Panama." ———Müller, Syn. Test. Viv., 1836, p. 191. "Legit H. Cuming ad Panamam." ———Reeve, Conch. Syst., Vol. 1, 1841, p. 110, pl. 85, fig. 8. ———Hanley, Cat. Rec. Bivalve Shells, p. 169, 1843, p. 376, ?1856, Suppl. pl. 19, fig. 54, 1846. "Panama."

Leda costellata Sowerby, Hanley, Thes. Conch., Vol. 3, 1860, p. 111, pl. 228 D-1,-4). 25-29 fathoms, mud, crushed shell and sand bottom; Cape San Lucas, September, 1871, sp. 24, pl. 4, fig. 24. "*Hab.* Panama." ———Zetek, *Rev. Nueva*, Nos. 1 & 2, 1918, p. 37. Panama. ———Strong, Hanna & Hertlein, *Proc. Calif. Acad. Sci.*, Ser. 4, Vol. 21, no. 10, 1933, p. 118. Acapulco, Mexico.

Leda (*Leda*) *costellata* Sowerby, Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, p. 375, 1908. Gulf of California to Panama. Sta. 2823, in 26 fathoms.

[54] See *Leda guppyi* Dall, Maury, *Bull. Amer. Paleo.*, Vol. 10, Bull. No. 42, p. 174 (22), pl. 23 (12), fig. 3, 1925. Manzanilla, Trinidad; Miocene.

[55] *Poroleda* Tate, *Jour. Roy. Soc. New South Wales*, Vol. 27, 1893, p. 186. "Examples: — *Scaphula* (?)*elongata*, Hutton, *Trans. N. Z. Inst.*, XVII., p. 332, 1885. *Poroleda lanceolata*, Tate." ———Cotton & Godfrey, Moll. South Australia, Pt. 1. Handbook of Flora and Fauna of South Australia, issued by South Australian Branch Brit. Sci. Guild. Adelaide, 1938, p. 45. Type: *Poroleda lanceolata* Hutton [Tate, 1893, p. 186, pl. 12, fig. 6. Gellibrand River, Australia; Eocene].

Leda rostellata Sowerby, Pilsbry & Lowe, *Proc. Acad. Nat. Sci. Philadelphia,* Vol. 84, 1932, p. 141. Acapulco, Mexico, dredged in 20 fathoms.

Type Locality: Panama, in 10 fathoms, sandy mud.

Range: Santa Inez Bay, Lower California, to Panama.

Collecting Stations: Mexico: Santa Inez Bay, Gulf of California (143-D-1,-4). 25-29 fathoms, mud, crushed shell and sand bottom; Cape San Lucas, Lower California; El Salvador: Meanguera Island, Gulf of Fonseca (199-D-1). 16 fathoms, sand, mud and crushed shell bottom; Costa Rica: 14 miles southeast of Judas Point (214-D-1-4). 42-61 fathoms, mud, shell and rocks on bottom.

Oblong, thin, covered with small concentric acute riblets; anteriorly beaked and acuminated, with two dorsal approximated and crenulated ribs (Hanley).

Several specimens of *Nuculana costellata* were collected, usually only one or two at a locality. Most of these specimens are very large compared to those which have appeared previously in the literature, but they do not differ otherwise.

Nuculana flexuosa[56], described from the lower Miocene of Florida, was compared to *N. costellata* by Heilprin but judging from the figures it does not appear to be very closely related to the west coast species.

Nuculana (Costelloleda) marella Hertlein, Hanna & Strong, sp. nov.

Plate II, Figures 12, 13.

[?] *Leda cestrota* Dall, Pilsbry & Lowe, *Proc. Acad. Nat. Sci. Philadelphia,* Vol. 84, 1932, p. 141. "Dredged at 20 fathoms. Acapulco."

Not *Leda cestrota* Dall, *Proc. U. S. Nat. Mus.*, Vol. 12, 1889, p. 255, pl. 13, fig. 7. "Hab. Station 2145, near Colon (Aspinwall), in 25 fathoms, mud."

Shell elongate, slender, compressed, thin, narrowly rostrate, white under a thin light brown epidermis; beaks low, at about the anterior third, posterior dorsal margin only moderately concave and the anterior slightly convex; sculptured with numerous, fine, close spaced concentric laminae; lunular depression very narrow, smooth; escutcheon long, narrow, microscopically striated, the valve margins distinctly elevated, bounded on each valve with two rays separated by a shallow depression running from the beaks to the end of the rostrum, on which the concentric laminae are stronger but flattened; anterior end with a broad, shallow depression running from the beaks to the basal margin; interior polished, hinge with 32 small teeth on the anterior side and about 50 on the posterior side of the central pit. The type measures: longitudinal diameter, 32 mm.; vertical diameter, 11.3 mm.; thickness of the two valves, 5.0 mm.

Holotype, a single specimen, is without definite locality although it probably came from the Gulf of California because it was collected during the expedition to the Gulf of California in 1936. About a dozen single valves and one specimen with both valves were collected at Sta. 221-D-1-5. Lat 7° 54′ 15″ to 7° 52′ 30″ N., Long. 82″ 02′ 45″ to 82° 01′ 00″ W., Gulf of Chiriqui, Panama, 35-40 fathoms, sandy mud bottom.

This species bears a slight resemblance to *Nuculana costellata* Sowerby, but is larger, more rostrate and possesses finer concentric sculpture. The new species bears some resemblance to *Nuculana cestrota* Dall, a species described from the Caribbean and reported by Pilsbry & Lowe from Acapulco, Mexico. The shell of *N. marella* has a greater altitude in proportion to the

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[56] *Leda flexuosa* Heilprin, *Trans. Wagner Free Inst. Sci.*, Vol. 1, 1887, p. 119, pl. 16, fig. 66. From the "Silex-bearing marl (Miocene) of Ballast Point, Hillsboro Bay," Florida. ———Dall, *U. S. Nat. Mus., Bull.* 90, 1915, p. 117, pl. 23, figs. 8 and 10.

length and is therefore not so slender, and the anterior and posterior dorsal slopes are straighter than those of the species described by Dall.

Subgenus **Thestyleda** Iredale.

Thestyleda Iredale, *Rec. Australian Mus.*, Vol. 17, no. 4, September 4, 1929, pp. 158, 187. "Type *Leda ramsayi* E. A. Smith."

Type (by original designation): *Leda ramsayi* E. A. Smith. [Sci. Rept. Voy. Challenger, Zool., Vol. 13, 1885, p. 241, pl. 20, figs. 3, 3a. "off Sydney, New South Wales, in 950 fathoms; green mud."]

Shell of medium size, thin, elongate, umbos slightly tumid, acutely rounded anteriorly, rostrate posteriorly; anterior dorsal slope short, posterior dorsal slope more than twice as long, concave in anterior half then almost straight; ventral margin convexly rounded anteriorly then continuing in an almost straight line to the posterior end which is squarely truncated; ornamented by well marked regular concentric rugae which turn upward at almost a right angle upon crossing the lower keel; two radiating ridges form keels along the rostrum; hinge, consisting of anterior and posterior series of chevron shaped teeth; chondrophore large.

The west American species *Nuculana hamata* and *N. cordyla* appear to be referable to the subgenus *Thestyleda*.

Nuculana (Thestyleda) hamata Carpenter.

Plate II, Figure 14.

Leda hamata Carpenter, *Rept. Brit. Assoc. Adv. Sci.* for 1863 (issued 1864), pp. 612, 644. "Santa Barbara; Cat. Is., 20-60 fm.; common." Reprint in *Smithson. Misc. Coll.*, No. 252, 1872, pp. 98, 130. ———Carpenter, *Proc. Calif. Acad. Sci.*, Vol. 3, February, 1866, p. 210. Coast of California. ———Cooper, *Geol. Surv. Calif., Geogr. Catalog.* Moll., 1867, p. 12. "Santa Barbara 16-28 fms. Catalina I.?" ———Sowerby, Conch. Icon., Vol. 18, *Laeda*, November, 1871, sp. 56, pl. 9, fig. 56. "*Hab.* Catalina Islands." ———Dall, *Proc. U. S. Nat. Mus.*, Vol. 24, 1902, p. 558, pl. 40, fig. 9. Near Catalina Island, California, in about 50 fathoms. ———Arnold, *Mem. Calif. Acad. Sci.*, Vol. 3, 1903, p. 97, pl. 17, fig. 4. Pliocene at Deadman Island, San Pedro, California. Pleistocene of San Pedro and San Diego, California. Recent from Santa Barbara to Santa Catalina Island. ———I. S. Oldroyd, *Stanford Univ. Publ. Univ. Ser. Geol. Sci.*, Vol. 1, no. 1, 1924, p. 23, pl. 6, fig. 4; pl. 37, fig. 5. "Type locality, Santa Barbara, California. Range: Puget Sound to Panama Bay. In the Pliocene and Pleistocene of California."

Nuculana hamata Carpenter, Grant & Gale, *Mem. San Diego Soc. Nat. Hist.*, Vol. 1, 1931, p. 125, pl. 1, figs. 14 and 15. Earlier records cited. Pleistocene and Recent.

Not *Zealeda hamata* Marwick, *Proc. Malacol. Soc. London*, Vol. 16, no. 1, April, 1924, p. 25, figs. 1 and 2 (p. 26). "*Locality.* ———Awatere Beds (Pliocene), east shore of Lake Grassmere, Marlborough, New Zealand."

Type Locality: Santa Barbara, California.

Range: Puget Sound to Panama Bay.

Collecting Station: Mexico: East of Cedros Island (126-D-12). 45 fathoms, crushed shell and mud bottom.

The shell of *Nuculana hamata* is extended into a long rostrum posteriorly which is squarely truncated at the end. The exterior of the shell is ornamented by strong concentric sculpture. The sculpture of the subspecies *Nuculana hamata limata* Dall[57] is very variable.

[57] *Leda hamata* Carpenter variety *limata* Dall, *Proc. U. S. Nat. Mus.*, Vol. 52, December 27, 1916, p. 397. "Off Santa Rosa Island, California, in 50 fathoms." I. S. Oldroyd, *Stanford Univ. Publ. Univ. Ser. Geol. Sci.*, Vol. 1, 1924, p. 24 (as *Leda hamata limata*). Type locality cited. Range: Santa Barbara to San Diego, California.

Nuculana (*Thestyleda*) *elaborata* Prashad[58] described from the East Indies, is a similar species.

Nuculana (Thestyleda) cordyla Dall.

Leda (*Leda*) *cordyla* Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 375, pl. 6, figs. 6 and 7. U. S. S. *Albatross* Station 3354, "Gulf of Panama, in 322 fathoms, mud, bottom temperature 46°F." Also at Station 2792, off Manta, Ecuador, in 401 fathoms.

Type Locality: Gulf of Panama, in 322 fathoms, mud. Type No. 122,915 U. S. Nat. Mus.

Range: Gulf of Panama to Manta, Ecuador, in deep water.

Shell, small, rostrate, with 14 anterior and 19 posterior hinge teeth. It is somewhat similar to *N. hamata*.

Subgenus **Spinula** Dall.

Spinula Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 377. "Type, *Leda calcar* Dall." ———Thiele, Handbuch syst. Weichtierkunde, Teil 3, 1934, p. 789. *L.* (*S.*) *calcar* Dall, cited.

Type (by original designation): *Leda calcar* Dall.

Shell rostrate, acute behind, smooth, with a well-developed short amphidetic ligament, an internal resilium supported by triangular chondrophores, a defined lunule and escutcheon; a long, slender, completely united siphon, no papal tentacles; pallial sinus obsolete (Dall).

Ledaspina Marwick[59] from the Tertiary of New Zealand "differs from *Spinula* Dall in being almost equilateral and not drawn out posteriorly."

Nuculana (Spinula) calcar Dall.

Leda (*Spinula*) *calcar* Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 378, pl. 10, figs. 1, 10. U. S. S. *Albatross* station 4658, "off the Peruvian coast, in S. Lat. 8° 30′, W. Lon. 85° 36′, in 2370 fathoms, green mud, bottom temperature 35°.3 F."

Type Locality: Off the coast of Peru, in Lat. 8° 30′ S., Long. 85° 36′ W., in 2370 fathoms, green mud. Type No. 110,573 U. S. Nat. Mus.

Range: Known only from the type locality.

Shell compressed and acutely rostrate; posterior dorsal margin nearly straight, posterior end acutely angular, with a wide shallow sulcus below, setting off the rostrum.

Nuculana (Spinula) calcarella Dall.

Leda (*Spinula*) *calcarella* Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 378. U. S. S. *Albatross* station 4656, "off the coast of Peru, in S. Lat. 6° 55′ and W. Lon. 83° 34′, in 2222 fathoms, green mud, bottom temperature 35°.2 F."

Type Locality: Off the coast of Peru, in Lat. 6° 55′ S., Long. 83° 34′ W., in 2,222 fathoms, green mud. Type No. 110,575 U. S. Nat. Mus.

Range: Known only from the type locality.

Shell smaller than *Nuculana calcar* and near the base there are six or eight lines not coincident with the lines of growth.

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58 *Nuculana* (*Thestyleda*) *elaborata* Prashad, Siboga Exped., Monogr. 53c, Lamell., 1932, p. 22, pl. 1, figs. 32, 33, 34. "Holotype and an odd valve brought up in a deep-sea trawl at St. 52 (9° 3′.4 S., 119° 56′ .7 E., 959 metres)."

59 Marwick, J., *Geol. Surv. New Zealand, Palaeo. Bull.* No. 13, 1931, p. 53. "Type (original introduction): *Ledaspina stimulea* n. sp. Oligocene, New Zealand," p. 53, pl. 2, figs. 21, 24. From Loc. 1240 "Ihungia mudstone, Island Creek, Tutamoe, S. D." Oligocene.

Subgenus **Jupiteria** Bellardi.

Jupiteria Bellardi, Mon. Nuculidi Terr. Terz. Piemonte e Liguria, 1875, p. 20. ———Dall, *Trans. Wagner Free Inst. Sci.*, Vol. 3, pt. 4, April, 1898, p. 579. "Type *L. concava* Bronn." ———Sacco, Moll. Terr. Terz. Piemonte e Liguria, Pt. 26, December, 1898, p. 56. "(Tipo *J. concava* (Brn.))."———Woodring, *Carnegie Inst. Washington, Publ.* 366, 1925, p. 18. Type: *Nucula concava* Bronn.

Type (designated by Dall): *Leda concava* Bronn. [=*Nucula concava* Bronn, Ital. Tert. Gebilde, 1831, p. 110. Italy. From "Ta. c." [="*Tabbiano*, links zwischen *Cq.* und *Parma*" in the "Jüngerer Grobkalk, blau, thonig, in den *Apenninen.*"] ———Sacco, Moll. Terr. Terz. Piemonte e Liguria, Pt. 26, December, 1898, p. 56, pl. 12, figs. 1, 2, 3. Several localities in the Pliocene of Italy].

Small corbuloid, strongly inflated shells; blunt and barely ridged rostrum; shallow sinus.

A few of the tropical west American species have been placed under *Jupiteria* by Dall but some of those are now believed to be referable to *Saccella*. It is probable however that some of the west American species may be referable to *Jupiteria*.

Jupiteria occurs in the Miocene and Pliocene of the Mediterranean region, in the Midway, early Tertiary of southeastern United States, and from Miocene to Recent in the Caribbean region. It has been recorded from the upper Eocene of California[60]. Marwick & Finlay[61] cited *Jupiteria* from the Danian, upper Cretaceous of New Zealand, Marwick[62] cited it from the Medial Tertiary, and Powell[63] described a species which he referred to *Jupiteria*, from the waters of New Zealand.

An Australian species, "*Leda fortis*[64]," was believed by Hedley to be referable to *Jupiteria* but Iredale considered the species to belong to his genus *Teretileda*.

The subgeneric position of the following species of *Nuculana* is uncertain.

Nuculana acrita Dall.

Leda (*Jupiteria*) *acrita* Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 374. U. S. S. *Albatross* Station 2799, "Panama Bay, in 29½ fathoms, mud." Also other localities in Panama Bay, in 14-62 fathoms.

Type Locality: Panama Bay, in 29½ fathoms, mud. Type No. 110,690 U. S. Nat. Mus.

Range: Panama Bay.

Shell small, white, subequilateral, inflated and acutely rostrate posteriorly; hinge with about 15 anterior and 13 posterior teeth. Length, 6.2 mm.; height, 3.8 mm.; diameter, 3.0 mm.

Nuculana agapea Dall.

Leda (*Jupiteria*) *agapea* Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 373, pl. 6, figs. 4 and 5. U. S. S. *Albatross* station 3360, "Gulf of Panama, in 1672 fathoms, sand, bottom temperature 42°F." Also off the coast of Ecuador in 1573 fathoms.

[60] *Jupiteria* (*Ledina*) *duttonae* Vokes, *Ann. New York Acad. Sci.*, Vol. 38, January 4, 1939, p. 44, pl. 1, fig. 6. From Loc. 1817 (Univ. Calif.), S. W. ¼ of N. W. ¼ of Sec. 15, T. 18 S., R. 14 E., 100 feet up the fourth small draw from west end of ridge; immediately opposite the place where Urruttia Canyon enters Salt Creek. Domengine formation, Eocene.

[61] Finlay, H. J., and Marwick, J., *Geol. Surv. New Zealand, Palaeo. Bull.* No. 15, 1937, p. 16.

[62] Marwick, J., *Geol. Surv. New Zealand, Palaeo. Bull* No. 13, 1931, pp. 51-53.

[63] *Nuculana* (*Jupiteria*) *manawatawhia* Powell, Discovery Repts., Vol. 15, 1937, p. 164, pl. 45, fig. 9. "*Habitat*: Off Three Kings Islands" New Zealand.

[64] *Leda fortis* Hedley, *Rec. Australian Mus.*, Vol. 6, no. 5, July 18, 1907, p. 362, pl. 66, figs. 2 and 3. Dredged from 800 fathoms, 35 miles east of Sydney, Australia, in the Tasman Sea.

Type Locality: Gulf of Panama, in 1,672 fathoms, sand. Type No. 122,911 U. S. Nat. Mus.

Range: Gulf of Panama to coast of Ecuador, in deep water.

This species is most nearly related to *L. pontonia* Dall, but has the beaks more anterior and the sculpture coarser and more deeply incised (Dall).

Nuculana bicostata Sowerby.

Laeda bicostata Sowerby, Conch. Icon., Vol. 18, *Laeda*, November, 1871, sp. 37, pl. 6, fig. 37. "*Hab.* Panama."

Type Locality: Panama.

Range: Known only from the type locality.

Shell arched, semi-ovate, compressed, covered with a pale epidermis, sculptured with nearly concentric ridges undulated at the back and beaded on the ribs; anterior side roundly sub-acuminated with ventral margin roundly convex; posterior side rayed with two crenulated arched ribs, dorsal margin depressed, concave, acute at the end; umbos rounded, elevated (Reeve).

The arched form and distinct elevated and curved posterior ribs seem to distinguish this shell from the varieties of *Laeda elenensis*. (Reeve).

Nuculana crispa Hinds.

Nucula crispa Hinds, *Proc. Zool. Soc. London*, December, 1843, p. 100. "*Hab.* Gulf of Nicoya; from thirty-six fathoms." ———Hinds, Zool. Voy. Sulphur, Moll., Pt. 3, 1844 [January, 1845 on cover], p. 64, pl. 18, fig. 14. Original locality cited.

Leda crispa Hinds, Hanley, Thes. Conch., Vol. 3, 1860, p. 134, pl. 229 (*Nuculidae*, pl. 4), figs. 107, 108. Gulf of Nicoya. ———Sowerby, Conch. Icon., Vol. 18, *Laeda*, November, 1871, sp. 55, pl. 9, fig. 55. "*Hab.* Gulf of Nocoyo."

Type Locality: Gulf of Nicoya, in 36 fathoms.

Range: Known only from the type locality.

The original illustration of this species shows a small rostrate form with strong concentric sculpture. There is a strong ridge on the rostrum and anterior to this is a narrowly elongate triangular depression separating the ridge from the remainder of the shell.

Nuculana cuneata Sowerby.

Plate I, Figures 20 and 21.

Nucula cuneata Sowerby, *Proc. Zool. Soc. London*, 1832 (issued March 13, 1833), p. 198. "*Hab.* ad Valparaiso." "Dredged in coarse sand and gravel, at various depths, from fourteen to forty-five fathoms." ———Sowerby, Conch. Illustr., *Nuculae*, 1833, p. 4, pl. 15, fig. 15. Valparaiso. New Guinea. ———Reeve, Conch. Syst., Vol. 1, 1841, p. 111, pl. 85, fig. 15. ———Philippi, Reise durch die Wueste Atacama, 1860, pp. 176-177. Valparaiso; Paposo, Chile.

Leda cuneata Sowerby, Hupé, Hist. de Chile, Zool., Vol. 8, 1854, p. 307. "Habita Valparaiso y otras partas de la República." ———Hanley, Thes. Conch., Vol. 3, 1860, p. 128, pl. 228 (*Nuculidae*, pl. 3), figs. 92, 93. ———Sowerby, Conch. Icon., Vol. 18, *Laeda*, September, 1871, sp. 35, pl. 6, figs. 35a, 35b. "*Hab.* Valparaiso, New Guinea."

Type Locality: Valparaiso, Chile, in from 14 to 45 fathoms, sand and gravel.

Range: Known with certainty only from the type locality.

Shell small, rostrate-ovate, with an ashy or greenish-olive periostracum, without conspicuous indented ray, and with concentric costellated sculpture.

Nuculana cuneata has been recorded from New Guinea but that record is believed to have been based on some similar but different species. According to Hanley[65], *"Leda inornata"* A. Adams[66], which was described from New Guinea, is identical with *Nuculana cuneata.* Dall (1909), however, considered *N. cuneata* to be identical with *N. acuta.*

Nuculana excavata Hinds.

Nucula excavata Hinds, *Proc. Zool. Soc. London,* December, 1843, p. 100. *"Hab.* Panama; dredged among mud in thirty fathoms."———Hinds, Zool. Voy. Sulphur, Moll. Pt. 3, 1844 [January, 1845 on cover], p. 64, pl. 18, fig. 17. Original locality cited.

Leda excavata Hinds, Hanley, Thes. Conch., Vol. 3, *Nuculidae,* 1860, p. 135, pl. 229 (*Nuculidae,* pl. 4), figs. 104, 105. Panama. ———Sowerby, Conch. Icon., Vol. 18, *Laeda,* September, 1871, sp. 38, pl. 6, figs. 38a, 38b. *"Hab.* Panama."

Type Locality: Panama, in 30 fathoms, mud.

Range: Known only from the type locality.

The original illustration of this species shows an ovate-rostrate shell with a rostral ridge, anterior ray, and concentric sculpture.

Nuculana hindsii Hanley.

Leda hindsii Hanley, *Proc. Zool. Soc. London,* 1860, p. 440. *"Hab.* Nicoyae fretum?" "Mr. Hinds referred this shell to his *Nucula crispa;* it is very distinct, however, from the delineated type." ———Hanley, Thes. Conch., Vol. 3, *Nuculidae,* 1860, p. 135, pl. 229 (*Nuculidae,* pl. 4), fig. 102. Gulf of Nicoya? ———Sowerby, Conch. Icon., Vol. 18, *Laeda,* November, 1871, sp. 60, pl. 9, fig. 60. *"Hab.* Gulf of Nicoya?"

Type Locality: ? Gulf of Nicoya, Costa Rica.

Range: Known only from the type locality.

A small, pointed, ovate-oblong shell with a conspicuous anterior indented ray and fold, and with concentric sculpture.

Nuculana lobula Dall.

Leda (Jupiteria) lobula Dall, *Bull. Mus. Comp. Zool.,* Vol. 43, no. 6, October, 1908, p. 375. U. S. S. *Albatross* station 3422, "in 141 fathoms, mud, off Acapulco, Mexico, bottom temperature 53°.5."

Type Locality: Off Acapulco, Mexico, in 141 fathoms, mud.

Range: Known only from the type locality.

Shell small, olivaceous, oval with regular rounded concentric threads; hinge with about 13 anterior and 9 posterior teeth.

Nuculana loshka Dall.

Leda (Leda) loshka Dall, *Bull. Mus. Comp. Zool.,* Vol. 43, no. 6, October, 1908, p. 376, pl. 17, fig. 2. U. S. S. *Albatross* station 3392, "Gulf of Panama, in 1270 fathoms, hard bottom, temperature 36°.4 F."

Type Locality: Gulf of Panama, in 1,270 fathoms, hard bottom. Type No. 122,916 U. S. Nat. Mus.

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[65] Hanley, S., Thes. Conch., Vol. 3, *Nuculidae,* 1860, explanation to figs. 92 and 93, pl. 228 (*Nuculidae,* pl. 3).

[66] *Leda inornata* A. Adams, *Proc. Zool. Soc. London,* June 16, 1856, p. 48. "Hab. New Guinea. Mus. Cuming."

Range: Known only from the type locality.

Shell thin, very inequilateral and posteriorly produced in a long rostrum; disk smooth but under a lens showing fine concentric and a few irregular faint radial striations.

Nuculana lucasana Strong & Hertlein.

Nuculana lucasana Strong & Hertlein, *Proc. Calif. Acad. Sci.*, Ser. 4, Vol. 22, no. 6, December 31, 1937, p. 160, pl. 34, figs. 9, 12, 13. "Lat. 23° 03′ to 23° 06′ N., Long. 109° 36′ to 109° 31′ W., dredged about 10 miles due east of San Jose del Cabo, Lower California, Mexico, in 20 to 220 fathoms."

Type Locality: East of San Jose del Cabo, Lower California, Mexico, in 20 to 220 fathoms. Type No. 6966 Calif. Acad. Sci. Paleo. Type Coll.

Range: Known only from the type locality.

Shell differing from *Nuculana lobula* Dall in the greater diameter in proportion to the height, and in the presence of an anterior radial depression, a feature not mentioned in the original description of Dall's species.

Nuculana ornata d'Orbigny.

Leda ornata d'Orbigny, Voy. Amér. Mérid., Vol. 5, 1846, p. 546, pl. 82, figs. 4-6. "rencontrée dans du sable de fond, recueilli à Payta (Pérou)." ———Hanley, Thes. Conch., Vol. 3, *Nuculidae*, p. 128, pl. 228 (*Nuculidae*, pl. 3), figs. 97, 98. Payta, Peru. ———Sowerby, Conch. Icon., Vol. 18, *Laeda*, September, 1871, sp. 36, pl. 6, figs. 36a, 36b, "*Hab.* Payta, Peru." ———Wolf, Geogr. & Geol. Ecuador (Leipzig), 1892, p. 631. Pliocene of Uimbí, Ecuador. Recent in region about Paita, Peru. ———Dall, *Proc. U. S. Nat. Mus.*, Vol. 37, 1909, p. 251. Paita, Peru.

Type Locality: Paita, Peru, sand.

Range: Known only from the type locality.

Shell ovate-elongate, rostrate, subventricose, with fine even concentric sculpture and a strong indented anterior ray.

Nuculana oxia Dall.

Leda oxia Dall, *Proc. U. S. Nat. Mus.*, Vol. 52, December 27, 1916, p. 395. "Station 2901, off Santa Rosa Island, California, in 48 fathoms, muddy bottom." ———Dall, *U. S. Nat. Mus., Bull.* 112, 1921, p. 11. Santa Rosa Island, California, to the Gulf of California. ———I. S. Oldroyd, *Stanford Univ. Publ. Univ. Ser. Geol. Sci.*, Vol. 1, 1924, p. 18. Type locality and range same as cited by Dall. ———E. K. Jordan, *Proc. Calif. Acad. Sci.*, Ser. 4, Vol. 15, no. 7, 1926, p. 244. San Quintin, Lower California; Pleistocene.

Nuculana oxia Dall, Grant & Gale, *Mem. San Diego Soc. Nat. Hist.*, Vol. 1, 1931, p. 125. Earlier records cited. ———Keen, Check List West North Amer. Mar. Moll. (Stanford Univ. Press), 1937, p. 23. Lat. 23°-34°N.

Type Locality: Off Santa Rosa Island, California, in 48 fathoms, mud. Type No. 214,448 U. S. Nat. Mus.

Range: Santa Rosa Island, California, to the Gulf of California.

Shell minute, very acute posteriorly, beaks subcentral; sculpture of regular equal concentric ridges with subequal interspaces; a depressed ray from beak to base anteriorly; hinge with about eight teeth on either side of the resilifer.

Nuculana peruviana Dall.

Leda (Leda) peruviana Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 377. "dredged in 1036 fathoms, mud, off Aguja Point, Peru, at station 4654."

Type Locality: Off Aguja Point, Peru, in 1,036 fathoms, mud.

Range: Known only from the type locality.

Shell large, slender, rostrate; surface mostly smooth but with a few coarse irregular wrinkles on basal half of disk anteriorly; hinge with about 15 anterior and 38 posterior teeth.

Nuculana pontonia Dall.

Leda pontonia Dall, *Proc. U. S. Nat. Mus.*, Vol. 12, 1889, p. 257, pl. 13, figs. 5, 5b. "Stations 2807, and 2808, in 812 and 634 fathoms, mud and sand, near the Galapagos Islands, Pacific Ocean; temperatures 38°.4 and 40°F." ———Dall, *U. S. Nat. Mus., Bull.* 112, 1921, p. 12. Santa Barbara Islands, California, to Peru and the Galapagos Islands, in deep water. ———I. S. Oldroyd, *Stanford Univ. Publ. Univ. Ser. Geol. Sci.*, Vol. 1, 1924, p. 20, pl. 1, figs. 4 and 5. Locality and range same as cited by Dall. ———Heath, *Mem. Mus. Roy. d'Hist. Nat. Belg.*, Ser. 2, Fasc. 10, 1937, pp. 5, 17, 20. Off San Diego, California, in 822 fathoms.

Leda (Jupiteria) pontonia Dall, Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 374. Off Galapagos Islands; Gulf of Panama; off San Diego, California; in 634 to 1672 fathoms.

Type Locality: Near the Galapagos Islands, in 634-812 fathoms, mud and sand.

Range: Santa Barbara Islands, California, to Peru, and the Galapagos Islands, in deep water.

Shell stout, strong, inflated with recurved pointed, posterior end; concentric sculpture of fine regular threads which become obsolete on the umbos; hinge with 16 anterior and 13 posterior teeth.

Nuculana rhytida Dall.

Leda (Leda) rhytida Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 376. U. S. S. *Albatross* station 3422, "off Acapulco, Mexico, in 141 fathoms, mud, bottom temperature 53°.5 F."

Type Locality: Off Acapulco, Mexico, in 141 fathoms, mud. Type No. 122,918 U. S. Nat. Mus.

Range: Known only from the type locality.

Shell small, elongate-ovate, translucent white, with olive-gray periostracum; posteriorly attenuated but not acute; sculpture of concentric riblets which become obsolete on upper posterior portion of shell; hinge with 11 anterior and nine posterior teeth.

Genus **Adrana** H. & A. Adams.

Adrana H. & A. Adams, Gen. Rec. Shells, Vol. 2, 1858, p. 547. ———Stoliczka, *Mem. Geol. Surv. India. Palaeont. Indica.* Cret. Fauna South India, Vol. 3, 1871, p. 320. "Type *Nuc.* [*Adrana*] *lanceolata*, Lam."

Type (designated by Stoliczka): *Nucula lanceolata* Lamarck. [Anim. s. Vert., Vol. 6, 1819, p. 58. No locality cited. According to d'Orbigny (Voy. Amér. Mérid., Vol. 5, 1846, p. 545), "Le véritable *N. lanceolata* de Lamarck est propre à la Nouvelle-Holland." According to Hanley (Thes. Conch., Vol. 3, 1860, explanation to pl. 227 (*Nuculidae*, pl. 2, fig. 35) it is *Leda taylori* from Guatemala. Chenu (Man. de Conchyl., Vol. 1, 1862, p. 180, fig. 904) gave an illustration of a shell cited as "A. lanceolata, *Lamarck*," but no locality was cited. The figure given by Chenu and the same figure given by Tryon but cited as *Leda (Adrana) sowerbyana* (Struct. and Syst. Conch., Vol. 3, 1884, pp. 249, 443, pl. 126, fig. 32. "Xipixapi") somewhat resembles

that of *Adrana electa* A. Adams (*Proc. Zool. Soc. London,* 1856, p. 48 (as *Leda electa*) "*Hab.* Santos, Brazil (*Capt. Martin*). Mus. Cuming." ——— Hanley, Thes. Conch., Vol. 3, 1860, p. 109, pl. 227 (*Nuculidae,* pl. 2), figs. 40, 41 (as *Leda electa*). Santos, Brazil. ———Sowerby, Conch. Icon., Vol. 18, *Laeda,* February, 1871, sp. 2, pl. 1, figs. 2a, 2b. "Hab. Santos, Brazil"), and so also does that of G. B. Sowerby cited as *Nucula lanceolata* Lamarck (Gen. Shells, pl. 102, fig. 1, which Hanley referred to *Leda electa*), and that of G. B. Sowerby II cited as *Laeda sowerbyana* (Conch. Icon., Vol. 18, *Laeda,* pl. 1, fig. 1a)].

The shells referred to this genus are very elongate, lanceolate, and often have nearly straight dorsal margins, the beaks scarcely projecting; the sculpture is fine and composed of concentric or somewhat oblique riblets.

Nine species of *Adrana* have been described from tropical west American waters. Three of these, *Adrana elongata* Sowerby, *A. sowerbyana* d' Orbigny and *A. suprema* Pilsbry & Olsson, have large shells with a nearly straight dorsal border. The others are smaller and the dorsal border slopes somewhat in each direction from the beak. No species of *Adrana* has been described from the Tertiary of western North America but several have been recorded from Eocene[67] to Recent in the southeastern part of the United States and from Miocene[68] to Recent in the Caribbean region. The genus has been recorded from the Oligocene of Peru. At the present time the genus *Adrana* appears to be entirely confined to the New World. One Recent species "*Leda metcalfii,*" cited from the Philippine Islands by Hanley and by Sowerby was originally described without information as to locality. We have not noticed it cited in the literature as present in recent collections from the Philippine Islands.

Key to the Species of *Adrana.*

A. Anterior and posterior dorsal margins forming a nearly straight line
  a. Umbos a little anterior to the center
    b. Ventral margin scarcely concave toward ends ..... *elongata*
    bb. Ventral margin distinctly concave toward ends producing more attenuate terminations ..... *sowerbyana*
  aa. Umbos central *suprema*

B. Anterior and posterior dorsal margins forming an obtuse angle at the umbos
  a. Beaks nearly central
    b. Branching riblets on anterior dorsal area ..... *tonosiana*
    bb. Anterior dorsal area without branching riblets ..... *arcuata*
  aa. Beaks slightly anterior to center
    c. Surface fully sculptured
      d. Anterior ventral margin narrowly constricted ..... *taylori*
      dd. Anterior ventral margin not constricted ..... *crenifera*
    cc. Posterior dorsal area smooth
      e. Concentric sculpture of coarse riblets ..... *exoptata*
      ee. Concentric sculpture fine ..... *penascoensis*

[67] *Adrana aldrichiana* Harris, *Proc. Acad. Nat. Sci. Philadelphia,* Vol. 47, April 9, 1895, p. 47, pl. 1, fig. 6 (under the genus *Leda*). "Brazos River, Tex., one and one-half miles below Mosley's Ferry." "Lower Claiborne. Eocene." — Harris, *Bull. Amer. Paleo.,* Vol. 6, No. 31, June 30, 1919, p. 71, pl. 25, figs. 20, 21.

[68] See Olsson, A. A., *Bull. Amer. Paleo.,* Vol. 9, Bull. No. 39, 1922, pp. 346-347 (174-175). ———Maury, Serv. Geol. e Miner. Brazil, Monogr. 4, 1924, p. 405. ———Mansfield, *Florida State Geol. Surv., Bull.* No. 8, 1932, p. 36.

Adrana arcuata Sowerby.

Laeda arcuata Sowerby, Conch. Icon., Vol. 18, *Laeda*, September, 1871, sp. 20, pl. 4, fig. 20. "*Hab.* . . . . . ?"

Nuculana arcuata Sowerby, Pilsbry & Olsson, *Nautilus*, Vol. 48, no. 4, 1935, p. 118, pl. 6, figs. 2 and 3. Point Ancon, Santa Elena, Ecuador. Also Ecuadorian and Peruvian coasts.

Type Locality: Not originally cited. Point Ancon, Santa Elena, Ecuador, here designated as type locality.

Range: Coasts of Ecuador and Peru.

Shell elongate with arcuate ventral margin; ornamentation of regular thread-like ribs over the entire surface.

Adrana crenifera Sowerby.

Nucula crenifera Sowerby, *Proc. Zool. Soc. London*, 1832 (issued March 13, 1833), p. 197. "*Hab.* ad Xipixapi." "It was dredged in sandy mud, at a depth of nine fathoms." ———Sowerby, Conch. Illustr., *Nuculae*, 1833, pp. 3, 6, pl. 14, fig. 3. "Xipixapi, Mr. Cuming." ———Reeve, Conch. Syst., Vol. 1, 1841, p. 110, pl. 84, fig. 1. ———Hanley, Cat. Rec. Biv. Shells, p. 167, 1843, p. 376, 1856?, Suppl. 19, fig. 51, 1846. Xipixapi.

Leda crenifera Sowerby, Hanley, Thes. Conch., Vol. 3, *Leda*, 1860, p. 110, pl. 227 (*Nuculidae*, pl. 2), figs. 37 and 38. Xipixapi. ———Sowerby, Conch. Icon., Vol. 18, *Laeda*, September, 1871, sp. 21, pl. 4, figs. 21a, 21b. "*Hab.* Xipixapi."

Yoldia (*Adrana*) *crenifera* Sowerby, Dall, *Proc. U. S. Nat. Mus.*, Vol. 37, 1909, p. 251. Jipijapa, Ecuador.

Type Locality: Xipixapi, Ecuador, in 9 fathoms, sandy mud.

Range: Known only from the type locality.

Transversely elongated, lanceolate, smooth, with very fine transverse striae, the dorsal margin carinated, the keel crenulated (Hanley).

Adrana janeiroensis E. A. Smith[69] from off Rio de Janeiro, Brazil, bears some resemblance to *A. crenifera*. A species of *Adrana* somewhat similar to *A. crenifera* has been mentioned by Olsson[70] as occurring in the Oligocene of Peru, and a species compared to *A. crenifera* was cited by Wolf[71] from the Pliocene of Ecuador. "*Nucula dorbignyi*" described by Philippi[72] from the Tertiary of Chile was compared to *Adrana crenifera*.

The species "*Leda metcalfi*" Hanley is very similar if not identical with *A. crenifera*. It was described by Hanley[73] without locality information. Later, Hanley[74] cited it from the Philippine Islands as did Sowerby[75]. Except for citation of the species in the paper by Faustino[76] we have not noticed a record of it from the Philippine Islands in any recent papers on the fauna of that region.

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69 *Adrana janeiroensis* E. A. Smith, Brit. Mus. (Nat. Hist.) Brit. Ant. ("Terra Nova") Exped., 1910. Nat. Hist. Rept. Zool., Vol. 2, no. 4, Moll. pt. 1, p. 98, pl. 2, fig. 16, 1913: "Off Rio de Janeiro in 40 fathoms. Lat. 22° 56′ S., Long. 41° 34′ W."

70 Olsson, A. A., *Bull. Amer. Paleo.*, Vol. 17, no. 63, 1931, p. 134 (38).

71 Wolf, T., Geogr. & Geol. Ecuador, (Leipzig), 1892, p. 631. Pliocene of Uimbí, Ecuador.

72 *Nucula dorbignyi* Philippi, Los Fos. Terc. i. Cuart. Chile, 1887, p. 188, pl. 41, fig. 10. "Es de Levu i está sobre un gran pedazo de roca dura."

73 Hanley, S., *Proc. Zool. Soc. London*, 1860, p. 370. "*Hab.* ———?"

74 Hanley, S., Thes. Conch., Vol. 3, 1860, expl. to pl. 227 (*Nuculidae*, pl. 2), fig. 34.

75 Sowerby, II, G. B., Conch. Icon., Vol. 18, *Laeda*, September, 1871, sp. 18, pl. 4, fig. 18.

76 Faustino, L. A., *Bur. Sci. Philippine Islands, Monogr.* 25, October 30, 1928, p. 18.

Adrana elongata Sowerby.

Plate II, Figure 16.

Nucula elongata Sowerby, *Proc. Zool. Soc. London,* 1832 (issued March 13, 1833), p. 197. "*Hab.* in Columbiâ Occidentali." "Dredged in sandy mud, at a depth of twelve fathoms, at Xipixapi." ———Sowerby, Conch. Illustr., *Nuculae,* 1833, pp. 3, 6, pl. 14, fig. 2. "Salango, Mr. Cuming." ———Müller, Synop. Test. Viv., 1836, p. 190. Original record cited. ———Reeve, Conch. Syst., Vol. 1, 1841, p. 110, pl. 84, fig. 2. ———Catlow & Reeve, Conch. Nomencl., 1845, p. 53. ———Hanley, Cat. Rec. Bivalve Shells, p. 167, 1843, p. 376, ?1856, Suppl. pl. 19, fig. 50, 1846. [Not accurate figure.]. West Colombia. ———d'Orbigny, Voy. Amér. Mérid., Vol. 5, 1846, p. 545. Original record cited.

Leda elongata Sowerby, Hanley, Thes. Conch., Vol. 3, 1860, p. 106, pl. 227 (*Nuculidae,* pl. 2), fig. 39. "Salango, W. Columbia." ———Sowerby, Conch. Icon., Vol. 18, *Laeda,* 1871, sp. 4, pl. 1, fig. 4. "*Hab.* Salango, West Columbia."

Not *Leda elongata* Treat, *Ann. de Paleo.,* Vol. 22, fasc. 2, 1933, p. 52, pl. 6, fig. 3. "Environs d'Ankitohazo; niveau inférieur." Madagascar. Permo-Triassic.

Yoldia (*Adrana*) *elongata* Sowerby, Dall, *Proc. U. S. Nat. Mus.,* Vol. 37, 1909, p. 251. Coast of Ecuador. ———Zetek, *Rev. Nueva,* Nos. 1 & 2, 1918, p. 51. Zoogeographical province of Panama.

Nuculana (*Adrana*) *sowerbyana* d'Orbigny, Strong, Hanna & Hertlein, *Proc. Calif. Acad. Sci.,* Ser. 4, Vol. 21, no. 10, 1933, p. 118. Acapulco, Mexico.

Not *Nucula* (*Adrana*) *sowerbyana* d'Orbigny.

Type Locality: Xipixapi, Ecuador, in 12 fathoms, sandy mud.

Range: Acapulco, Mexico, to Ecuador.

Collecting Stations: Guatemala: 7 miles west of Champerico (197-D-1-2). 14 fathoms, mud bottom; El Salvador: La Libertad (198-D-2). 14 fathoms, mud bottom.

Specimens from three localities appear referable to *Adrana elongata* Sowerby. The application of the specific name *elongata* to this species is somewhat unfortunate because the species is not as elongate in form as is *Adrana sowerbyana,* a similar species. The beaks are more central and the ends much less tapering on *A. elongata* than is the case in *A. sowerbyana.* Another large species of the genus is *Adrana suprema* Pilsbry & Olsson with a length of 107 mm. It differs from *A. elongata* Sowerby in that the beaks are nearly central rather than somewhat anterior as in the species described by Sowerby.

Adrana exoptata Pilsbry & Lowe.

Plate II, Figure 11.

Leda (*Adrana*) *exoptata* Pilsbry & Lowe, *Proc. Acad. Nat. Sci. Philadelphia,* Vol. 84, p. 107, pl. 17, figs. 8 and 9, May 21, 1932. "Mexico: Guaymas, 20 fathoms."

Type Locality: Guaymas, Mexico, in 20 fathoms. Type No. 155633 Acad. Nat. Sci. Philadelphia.

Range: Guaymas, Sonora, Mexico, to Tangola-Tangola, Oaxaca, Mexico.

Collecting Stations: Mexico: 4 miles south-southwest of Maldanado Point (192-D-1). 26 fathoms, mud bottom; Santa Cruz Bay (195-D-21). 18 fathoms, mud bottom; Tangola-Tangola Bay (196-D-17). 4 fathoms, sand bottom.

The shell of this elongate form possesses a smooth band anterior to the posterior carina. The concentric sculpture on the anterior part of the shell becomes obsolete and grades into the smooth area. Some of the specimens in the present collection are slightly upturned at the posterior ex-

tremity of the shells but others barely show this feature and seem to agree almost exactly with *Adrana exoptata* Pilsbry & Lowe. *Adrana newcombi* Angas[77] described from the east side of the isthmus of Panama appears to be a very similar species.

Adrana penascoensis Lowe.

[?]*Yoldia* apparently *electa* A. Adams, Dall, *Amer. Jour. Conch.*, Vol. 7, no. 2, November 2, 1871, p. 154. From the head of the Gulf of California.

Leda (*Yoldia*) *lanceolata* Lamarck, Stearns, *Proc. U. S. Nat. Mus.*, Vol. 17 1894, p. 147. Gulf of California.

Leda (*Adrana*) *penascoensis* Lowe, *Trans. San Diego Soc. Nat. Hist.*, Vol. 8, no. 6, March 21, 1935, p. 18, pl. 1, fig. 8. "Punta Peñasco, Sonora, dredged 10 fathoms."

Type Locality: Punta Peñasco, Sonora, Mexico, in 10 fathoms. Type No. 11393 Lowe Coll. in San Diego Soc. Nat. Hist.

Range: Gulf of California.

Shell white, with a straw-colored glossy periostracum; strongly compressed beaks much nearer the anterior end. Dorsal line nearly straight, ventral margin curved, anterior and posterior ends about equally angular. Dorsal edges of both valves slightly crenate the entire length. Sculpture of fine concentric lines of growth over the entire surface of both valves, except a narrow portion bordering the posterior dorsal margin, which is entirely smooth. Diameter 37.5 mm., altitude 9.4 mm. (Lowe).

Adrana sowerbyana d'Orbigny.

Nucula lanceolata Lamarck, Sowerby, Conch. Illustr., *Nuculae*, 1833, p. 3, pl. 14, fig. 1. "Xipixapi." ———Deshayes, ed. of Lamarck's Anim. s. Vert., Vol. 6, 1835, p. 504. [No locality cited]. ———Reeve, Conch. Syst., Vol. 1, 1841, p. 110, pl. 84, fig. 1. ——— Hanley, Cat. Bivalve Shells, Suppl. pl. 19, fig. 49, 1846.

Not *Nucula lanceolata* J. Sowerby, Miner. Conch., Vol. 2, 1817, p. 178, pl. 180, fig. 1. "At Bawdsey, Suffolk, in Crag."

Not *Nucula lanceolata* Lamarck, Anim. s. Vert., February-June, 1819, p. 58. "Habite ....."

Leda sowerbyana d'Orbigny, Voy. Amér. Mérid., Vol. 5, 1846, p. 544. Reference cited "*Nucula lanceolata*, Sow., 1831, Gen. of Shells, no. 17, fig. 1 (non *Lanceolata*, Lamk., 1819)." "Elle a été pêchée par M. Cuming à la côte de Xipixapi, république de l'Équateur."

[?] *Nucula elongata* Sowerby, Valenciennes, Voy. Venus, Zool., Moll., 1846, pl. 23, fig. 4 (two figs.).

Leda sowerbiana d'Orbigny, Hanley, Thes. Conch., Vol. 3, 1860, p. 107, pl. 227 (*Nuculidae*, pl. 2), fig. 33. Xipixapi.

Laeda sowerbyana d'Orbigny, Sowerby, Conch. Icon., Vol. 18, *Laeda*, November, 1871, sp. 1, pl. 1, fig. 1b (only). "*Hab.* Xipixapi."

Yoldia (*Adrana*) *sowerbyana* d'Orbigny, Dall, *Proc. U. S. Nat. Mus.*, Vol. 37, 1909, p. 251. "Jipijapa, Ecuador." ———Zetek, *Rev. Nueva*, Nos. 1 & 2, 1918, p. 51. Panamanian zoogeographical province.

Type Locality: Xipixapi, Ecuador.

Range: Panama to Ecuador.

A few specimens in the collection appear to be intermediate between *Adrana sowerbyana* and *A. elongata*. The shell of *Adrana sowerbyana* d'Orbigny is similar to *Adrana elongata* Sowerby but is narrower and with more tapering extremities. Hanley believed that the specimen figured by

[77] *Leda* (*Adrana*) *newcombi* Angas, *Proc. Zool. Soc. London*, March 5, 1878, p. 314, pl. 18, figs. 16, 17. "*Hab.* Dredged in Navy Bay, Aspinwall, in 8 fathoms."

Valenciennes as "*Nucula elongata*" Sowerby might probably be referred to *sowerbyana*. The figure given by Valenciennes is somewhat less tapered at the ends than *sowerbyana* but otherwise it is quite similar. Stearns cited *Adrana sowerbyana* (as *L. lanceolata*) from the Gulf of California but Lowe described *Adrana penascoensis* from that region and Pilsbry & Lowe in discussing *Adrana exoptata* stated that *A. elongata* and *A. sowerbyana* occur much further south. *A. scaphoides* Rehder[78] from eastern Colombia is a similar species.

The name *Adrana sowerbyana* presents some complications in regard to nomenclature. *Nucula lanceolata* J. Sowerby was originally described as a fossil from the Pliocene of England in 1817. Lamarck also described under the same name in 1819, a Recent shell without locality information. G. B. Sowerby in the Genera of Shells (No. 17, 1825, pl. 102, fig. 1) illustrated a species under the name of *Nucula lanceolata* Lamarck but without information as to locality, while in 1833 G. B. Sowerby Jr. (Conch. Illustr., Nuculae, p. 3, pl. 14, fig. 1) illustrated a shell as *Nucula lanceolata* Lamarck with the locality as Xipixapi, which is in western Colombia, and also cited a reference to the figure in the Genera of Shells. d'Orbigny in 1846 noticed that the name *Nucula lanceolata* of Lamarck was preoccupied by the same combination of names used by J. Sowerby, hence d'Orbigny proposed for Lamarck's species the new name *Leda sowerbyana* and stated that it was collected at Xipixapi by Cuming. This evidently refers to the shell and locality in Conchological Illustrations although in the synonymy d'Orbigny cited the reference to the illustration in the Genera of Shells. Hanley in 1860 described "*Leda*" *taylori* from Guatemala and in the synonymy cited the reference to *Nucula lanceolata* of Lamarck and to the figure of *Nucula lanceolata* given by Sowerby in the Conchological Illustrations while the illustration of *N. lanceolata* in the Genera of Shells is referred by Hanley to *Leda electa* A. Adams from Brazil. Sowerby in 1871 referred the illustration, of *N. lanceolata* Lamarck in the Genera of Shells to "*Leda*" *sowerbyana*.

Although d'Orbigny stated that the true *Nucula lanceolata* Lamarck came from New Holland, it does not appear to have been recognized subsequently in that region. The figure in the Genera of Shells, which has a distinctly curved anterior dorsal margin and rounded anterior ventral margin, appears to be distinct from the one in the Conchological Illustrations which has an almost straight dorsal margin and is attenuated at both ends. We therefore follow Hanley in referring this figure (1833) to the west American *sowerbyana* while the one in the Genera of Shells (1825) may be referred to the east American "*Leda*" *electa* A. Adams.

"*Nucula darwini*[79]" described by Philippi from the Tertiary of Chile was compared to "*N. lanceolata* Sow."

Adrana suprema Pilsbry & Olsson.

Nuculana (*Adrana*) *suprema* Pilsbry & Olsson, *Nautilus*, Vol. 48, no. 4, April, 1935, p. 117, pl. 6, fig. 1. "Beach between Port Guanico and the mouth of the Guanico river, Los Santos province, Panama."

Type Locality: Beach between Port Guanico and the mouth of the Guanico river, Los Santos province, Panama.

Range: Known only from the type locality.

Shell resembling *Adrana elongata* but with the beaks nearly central.

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[78] *Adrana scaphoides* Rehder, *Nautilus*, Vol. 53, no. 1, July, 1939, p. 17, pl. 6, fig. 5. "Near Cartagena, Colombia."

[79] *Nucula darwini* Philippi, Los Fos. Terc. i Cuart. Chile, 1887, p. 188, pl. 41, fig. 17, From same locality as *Nucula darwini*, that is, "Es de Levu i está sobre un gran pedazo de roca dura."

Adrana taylori Hanley.

Leda taylori Hanley, *Proc. Zool. Soc. London*, 1860, p. 370. "*Hab.* Guatemala." ———Hanley, Thes. Conch., Vol. 3, 1860, p. 109, pl. 227 (*Nuculidae*, pl. 2), fig. 35. "Guatemala." ———Sowerby, Conch. Icon., Vol. 18, *Laeda*, September, 1871, sp. 17, pl. 4, fig. 17. "*Hab.* Guatemala."

Type Locality: Guatemala.

Range: Known only from the type locality.

Sowerby (1871) in discussing *Adrana arcuata* stated that "In *Leda taylori*, which resembles this species, there is peculiar narrowness and almost a constriction in the ventral margin at the anterior end not observable in *Laeda arcuata*." *Adrana taylori* is similar to *A. crenifera* Sowerby and *A. electa* A. Adams[80].

Adrana tonosiana Pilsbry & Olsson.

Plate II, Figure 15.

Nuculana (*Adrana*) *tonosiana* Pilsbry & Olsson, *Nautilus*, Vol. 48, no. 4, April, 1935, p. 117, pl. 6, fig. 4. "Estero Bucaru, mouth of the Tonosi River, Los Santos, Panamá."

Type Locality: Estero Bucaru, Mouth of Tonosi River, Los Santos Province, Panama. Type No. 164025 Acad. Nat. Sci. Philadelphia.

Range: Off Mazatlan, Sinaloa, Mexico, to Panama.

Collecting Stations: Guatemala: 7 miles west of Champerico (197-D-1-2). 14 fathoms, mud bottom; El Salvador: La Libertad (198-D-1-2). 13-14 fathoms, mud bottom; Nicaragua: Corinto (200-D-19). 12-13 fathoms, mangrove leaves on bottom; Panama: Gulf of Chiriqui (221-D-1-5). 35-40 fathoms, sandy mud bottom.

A large series of specimens dredged off Central America have been referred to *Adrana tonosiana* Pilsbry & Olsson. There seems but little difference between these and young *Adrana arcuata* Sowerby. According to Pilsbry & Olsson *tonosiana* is a smaller form, their specimens not exceeding 26 mm. Some of the specimens in the present collection attain a length of 33 mm. We have assigned these to *tonosiana* chiefly due to the strong and sometimes branching ribbing on the anterior dorsal margin. This was considered by Pilsbry & Olsson to be a characteristic feature of *tonosiana* and not present on *A. arcuata* Sowerby. If this is constantly absent on *A. arcuata* it would seem best to leave *tonosiana* as a valid species, otherwise they are extremely similar. A few irregular radial striae are present on the exterior of the shells in the present collection but these were not mentioned in the description of Pilsbry & Olsson. A single somewhat worn right valve from Sta. 221-D-1-5 has also been assigned to *A. tonosiana* because of the branching ribbing on the anterior dorsal edge. The shell is larger than the type of *A. tonosiana* and has a more pointed posterior end.

Adrana crenifera Sowerby is somewhat similar in form but the dorsal margin has a greater slope from the beak and the edge of the posterior ridge is said to be angular and decidedly crenulated.

Genus **Yoldia** Möller.

Yoldia Möller, Naturhist. Tidsskrift, IV (1), 1842, p. 91, also Index Moll. Groenlandiae, 1842, p. 18. Species cited: "*Y. arctica*, Nucula arctica Gray" and "*Y. angularis* nob., *Nuc. myalis* Couth.?" ———S. A. Miller, North Amer. Geol. and Palaeo., (Cincinnati, Ohio), 1889, p. 516. "Type *Y. myalis*," fig. 935.

[80] *Leda electa* A. Adams, See Hanley, Thes. Conch., Vol. 3, 1860, p. 109, pl. 227 (*Nuculidae*, pl. 2), figs. 40 and 41. "Santos, Brazil." ———Sowerby, Conch. Icon., Vol. 18, *Laeda*, February, 1871, sp. 2, pl. 1, figs. 2a, 2b. "*Hab.* Santos Brazil."

———Verrill & Bush, *Proc. U. S. Nat. Mus.*, Vol. 20, June 15, 1898, p. 858. "Type. ———*Yoldia hyperborea* Torrell=*Yoldia arctica* Möller (not Gray)." ———Cossmann, *Act. Soc. Linn. Bordeaux*, Vol. 66 (Conch. Neog. Aquit., Vol. 2, Livr. 1), 1912, p. 113. Genotype: *L. hyperborea* Loven. ———Gardner, Geol. Surv. Maryland. Upper Cretaceous, 1916, p. 518. "Type. ———*Yolida arctica* Gray." ———Woodring, *Carnegie Inst. Washington, Publ.* 366, 1925, p. 21. Type: "*Nucula arctica* Möller not Gray (=*Nucula myalis* Couthouy)." ———Stewart, *Acad. Nat. Sci. Philadelphia, Spec. Publ.* No. 3, 1930, p. 59. Type designation of Verrill & Bush accepted. ———Grant & Gale, *Mem. San Diego Soc. Nat. Hist.*, Vol. 1, 1931, p. 126. Type: *Nucula arctica* Gray.

Type (designated by Gardner): *Nucula arctica* Gray. [Suppl. to Ap. Parry's First Voy., 1819-1820, p. 241, 1824. ————Also illustrated by Grant & Gale, *Mem. San Diego Soc. Nat. Hist.*, Vol. 1, 1931, pl. 1, figs. 10, 11 (figures copied from Mossevich, *Acad. Sci. Union Republ. Soviet Socialist.*, Livr. 19, 1928, pl. 1, figs. 1 and 3). Circumboreal].

Somewhat similar to *Nuculana* but with thinner, subovate shell, slightly rostrate, usually gaping posteriorly; exteriorly sculptured by growth-lines or concentric striae; hinge consisting of two subequal series of small chevron-shaped teeth; resilium-pit large, symmetrically underlapping both rows of teeth; pallial sinus deep and wide, the apex broadly U-shaped.

There is considerable disagreement among various authors as to the designation of the type species of *Yoldia*. Grant & Gale have given a discussion of the problem. The designation of *Yoldia myalis* Couthouy by Miller in 1889 is not strictly valid due to the fact that in the original list of species under *Yoldia* it was cited as "*Nuc. myalis* Couth.?" and is thus a *species inquirenda* and not acceptable under the present rules of nomenclature. The interpretation of the type of *Yoldia* as indicated by Grant & Gale appears to be the correct one, and the type here accepted is *Nucula arctica* Gray. *Yoldia* probably ranges from Eocene to Recent, although it has been recorded from the Carboniferous. Several species of the genus *Yoldia* have been described from the Eocene of Western North America.

Microyoldia Verrill & Bush[81], with the type *M. regularis* Verrill, has not been recorded from tropical west American waters.

Subgenus **Katadesmia** Dall.

Katadesmia Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1898, p. 379. Sole species: *Yoldia* (*Katadesmia*) *vincula* Dall. ———Thiele, Handbuch Syst. Weichtierkunde, Teil 3, 1934, p. 790. *Y.* (*K.*) *vincula* Dall, cited.

Type (by original designation and by monotypy): *Yoldia* (*Katadesmia*) *vincula* Dall.

Southern species with well-defined functional opisthodetic ligament.

Yoldia (Katadesmia) vincula Dall.

Yoldia (*Katadesmia*) *vincula* Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 379, pl. 5, fig. 5. U. S. S. *Albatross* station 3360, "in 1672 fathoms, sand, Gulf of Panama, bottom temperature 42° F." Also at stations 3354 and 3361, in 322 fathoms, and in 1471 fathoms.

Yoldia vincula Dall, Zetek, *Rev. Nueva*, Nos. 1 & 2, 1918, p. 38. Panama.

Type Locality: Gulf of Panama, in 1,672 fathoms, sand. Type No. 122,903 U. S. Nat. Mus.

Range: Gulf of Panama.

[81] *Microyoldia* Verrill & Bush, *Amer. Jour. Sci.*, Ser. 4, Vol. 3, January, 1897, p. 56. "Type *M. regularis* (V.)," figs. 5 and 6 (p. 60). ———Verrill & Bush, *Proc. U. S. Nat. Mus.*, Vol. 20, 1898, p. 860. Type: *Microyoldia regularis* Verrill, p. 860, pl. 78, figs. 5 and 6.

The species is notable for its pale color and brilliant polish (Dall). Shell with the general form of *Sanguinolaria rosea;* hinge with 15 anterior and about 25 posterior teeth.

Subgenus **Megayoldia** Verrill & Bush.

Megayoldia Verrill & Bush, *Amer. Jour. Sci.*, Ser. 4, Vol. 3, January, 1897, p. 55. "Type *M. thraciaeformis* (Storer)," fig. 17. ———Verrill & Bush, *Proc. U. S. Nat. Mus.*, Vol. 20, 1898, p. 859. Type: *Megayoldia thraciaeformis* (Storer).

Type (by original designation): *Megayoldia thraciaeformis* (Storer). [=*Leda thraciaeformis* Storer, *Boston Jour. Nat. Hist.*, Vol. 2, 1838, p. 122, text fig. ". . . from the stomach of a Platéssa ———the dentàta of Mitchill ———called by our fishermen, *Sand dab*: ———this fish was caught off Provincetown, Cape Cod, in about thirty fathoms of water." ———I. S. Oldroyd, *Stanford Univ. Publ. Univ. Ser. Geol. Sci.*, Vol. 1, 1924, p. 27, pl. 5, fig. 1. Arctic Ocean to Oregon and Puget Sound. Also Atlantic].

Broad, compressed form, with a very blunt, indefinite, postero-dorsal rostrum, and with a low radial ridge, ending in a postero-ventral marginal lobe. The chondrophore is remarkably large and strong, concave, striated within, and projects much within the margin of the hinge-plate. The pallial sinus is large and deep. Ligament external, strongly developed (from Verrill & Bush).

Megayoldia is known in the Oligocene and probably occurs from Eocene to Recent. *Yoldia emersoni* Dall[82] described from the Eocene of Alaska may belong to this subgenus. Makiyama[83] has discussed the relationships of several Japanese species belonging to *Megayoldia.*

Yoldia (Megayoldia) martyria Dall.

Yoldia martyria Dall, *Nat. Hist. Soc. Brit. Columbia, Bull.* No. 2, January, 1897, p. 9, pl. 2, fig. 15. "Puget Sound, 35-135 fms.; Gulf of California off the Island of San Pedro Martir, in 65 fms.; U. S. Fish Commission steamer Albatross." ———Dall, Checklist Rec. Biv. Moll. (Southwest Museum), 1916, p. 11. Kasa-an Bay, Alaska, to Gulf of California. ———Dall, *U. S. Nat. Mus., Bull.* 112, 1921, p. 13. Kasaän Bay, Alaska, to Gulf of California. ———I. S. Oldroyd, *Stanford Univ. Publ. Univ. Ser. Geol. Sci.* Vol. 1, 1924, p. 29, pl. 39, fig. 11. Type locality and range same as cited by Dall. ———Keen, Check List West North Amer. Mar. Moll. (Stanford Univ. Calif.), 1937, p. 27. Range: Lat. 23°-55° N.

Type Locality: (According to I. S. Oldroyd), off San Pedro Martir Island, Gulf of California. Type in U. S. Nat. Mus.

Range: Kasaän Bay, Alaska, to the Gulf of California.

Shell olive-greenish, smooth, nearly equilateral; posterior end roundly pointed, compressed and slightly recurved; hinge with 21 anterior and 17 posterior teeth.

Subgenus **Orthoyoldia** Verrill & Bush.

Orthoyoldia Verrill & Bush, *Amer. Jour. Sci.*, Ser. 4, Vol. 3, 1897, p. 55. "Type *Orthoyoldia scapina* (Dall)." ———Verrill & Bush, *Proc. U. S. Nat. Mus.*, Vol. 20, 1898, p. 859. Type: *Orthoyoldia scapina* (Dall).

Type (by original designation): *Orthoyoldia scapina* (Dall). [=*Yoldia scapania* Dall, *Proc. U. S. Nat. Mus.*, Vol. 12, 1889, p. 254, pl. 13, fig.

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[82] *Yoldia emersoni* Dall, Harriman Alaska Exped., Vol. 4, 1910, p. 104, pl. 9, fig. 8. "Upper beds, 3373." Beds near the camp on the eastern side of Chichagof Cove. Upper beds of Stepovak Series. Eocene.

[83] Makiyama, J., *Mem. Coll. Sci. Kyoto Imper. Univ.*, Ser. B, Vol. 10, no. 2, 1934, pp. 130-132.

6. U. S. Fish Commission station 2762, "east of Rio Janeiro, in 59 fathoms, mud; bottom temperature 57°F."].

Shell oblong, gaping, blunt or rounded at both ends, without a distinct rostrum; no carina. Pallial sinus large and broad. Teeth numerous in both series (Verrill & Bush).

The shells of *Orthoyoldia* are soleniform or elongate-elliptic in shape.

Orthoyoldia is known from the Miocene[84] of the Caribbean region. It is now living in that region and is represented by at least one species in tropical west American waters.

Yoldia (Orthoyoldia) panamensis Dall.

Yoldia (*Orthoyoldia*) *panamensis* Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 380. U. S. S. *Albatross* station 3354, "Gulf of Panama, in 322 fathoms, mud, bottom temperature 46° F." Also at station 3355, in 182 fathoms.

Yoldia panamensis Dall, Zetek, *Rev. Nueva*, Nos. 1 & 2, 1918, p. 38. Panama.

Type Locality: Gulf of Panama, in 322 fathoms, mud. Type No. 122,900 U. S. Nat. Mus.

Range: Gulf of Panama.

The shell of this species is small, narrow, elongate, and very inequilateral; resilium small, vertical, triangular and wholly internal; no visible external ligament; hinge with 18 anterior and 52[?25]-27 posterior teeth.

Subgenus ***Yoldiella*** Verrill & Bush.

Yoldiella Verrill & Bush, *Amer. Jour. Sci.*, Ser. 4, Vol. 3, January, 1897, p. 55. "Type *Yoldiella lucida* (Loven)," figs. 3, 4, 11, 14. ———Verrill & Bush, *Proc. U. S. Nat. Mus.*, Vol. 20, 1898, p. 861. Type: *Yoldiella lucida* (Lovén).

Type (by original designation): *Yoldiella lucida* (Lovén). [=*Yoldia lucida* Lovén, *K. Vet. Akad. Förh.*, 1846 (Index Moll. Lit. Scandinaviae occid. Habit.), p. 34. "Boh.-Finm." Illustrated as *Portlandia lucida* Loven, by Sars, Bid. Kundsk. Norg. Ark. Fauna. I. Moll. Reg. Arct. Norvegiae, 1878, p, 37, Tab. 4, figs. 8a, 8b. West Coast of Norway in 20-650 fathoms. Also in Arctic and north Atlantic. ———Verrill & Bush, *Proc. U. S. Nat. Mus.*, Vol. 20, 1898, p. 861, pl. 77, fig. 2; pl. 80, fig. 3 (as *Yoldiella lucida*)].

This group includes a large number of small, mostly deep-sea species, with glossy, iridescent, ovate, and usually wedge-shaped shells, nearly always having a slight postero-ventral sinuosity, which feebly defines an obscure, blunt, rostral region, without any definite carination. The shells do not gap, but close tightly, except that at the rostral angle of some species there may be a slight divergence. The internal cartilage, which is often relatively large, occupies a simple notch, which interrupts the hinge margin more or less completely and generally shows externally in a dorsal view; the notch usually terminates within on the inner or inferior surface of the hinge-plate, and is often bounded within by a slight ridge. A weak external ligament is present on the postero-dorsal margin. A relatively small, pallial sinus has been observed in several of the species, but is usually indistinct. The siphon tubes, as observed in a few of the species, are slender and united for more than half their length. (Verrill & Bush).

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[84] See *Yoldia* (*Orthoyoldia*) *ovalis* Gabb, Woodring, *Carnegie Inst. Washington, Publ.* 366, 1925, p. 22, pl. 1, figs. 20, 21. Bowden, Jamaica: Miocene. *Yoldia bocasensis* Olsson (*Bull. Amer. Paleo.*, Vol. 9, Bull. No. 39, 1922, p. 348 (176), pl. 31 (28), figs. 21, 22. "Gatun Stage: Bocas del Toro") from the Miocene of Panama, is a similar species.

Yoldia (Yoldiella) cecinella Dall.

Yoldia cecinella Dall, *Proc. U. S. Nat. Mus.*, Vol. 52, December 27, 1916, p. 399. "Station 2823, off La Paz, Gulf of California, in about 26 fathoms." ———Dall, *U. S. Nat. Mus., Bull.* 112, 1921, p. 14. Aleutian Islands to Gulf of California. ———I. S. Oldroyd, *Stanford Univ. Publ. Univ. Ser. Geol. Sci.*, Vol. 1, 1924, p. 34. Type locality and range same as cited by Dall. ———Keen, Check List West North Amer. Mar. Moll. (Stanford University Press), 1937, p. 27. Lat. 23°-55° N.

Type Locality: Off La Paz, Lower California, Mexico, in about 26 fathoms. Type No. 211,424 U. S. Nat. Mus.

Range: Aleutian Islands to the Gulf of California.

Shell minute, polished, smooth, nearly equilateral, the margins arcuate above and below, the anterior end rounded, the posterior more pointed and slightly longer; beaks low and inconspicuous, with neither lunule nor escutcheon indicated; hinge with 6 or 7 minute teeth on each side of the subumbonal, very small resilifer. Length, 5 mm.; height, 2.6 mm.; diameter, 1.5 mm. (Dall).

Yoldia (Yoldiella) chilenica Dall.

Yoldia (*Yoldiella*) *chilenica* Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 380. U. S. S. *Albatross* station 2781 "on the southern coast of Chile (Lat. 51° 52′ S.), in 348 fathoms, mud, bottom temperature 50° F." Also at station 2782, in 258 fathoms.

Type Locality: Southern coast of Chile (Lat. 51° 52′ S.), in 348 fathoms, mud. Type No. 96,923 U. S. Nat. Mus.

Range: Southern coast of Chile.

This species has not been illustrated but according to Dall it has somewhat the appearance of young *Yoldia thraciaeformis*. Hinge with 19 anterior and 17 posterior teeth.

Yoldia (Yoldiella) dicella Dall.

Yoldia (*Yoldiella*) *dicella* Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 382. U. S. S. *Albatross* station 3418, "off Acapulco, Mexico, in 660 fathoms, sand, bottom temperature 39° F."

Type Locality: Off Acapulco, Mexico, in 660 fathoms, sand. Type No. 122,917 U. S. Nat. Mus.

Range: Known only from the type locality.

This is said to be a "spade-shaped" little species quite distinct from others of the genus in west American waters. Hinge with about 10 anterior and 15 posterior teeth.

Yoldia (Yoldiella) granula Dall.

Yoldia (*Yoldiella*) *granula* Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 382. U. S. S. *Albatross* station 2778, "in Magellan Straits, in 61 fathoms, bottom temperature 47 .9 F."

Type Locality: Magellan Straits, in 61 fathoms. Type No. 110,693 U. S. Nat. Mus.

Range: Known only from the type locality.

Shell minute, oval, equilateral, moderately tumid, smooth, covered with a polished straw-colored periostracum; interior porcellanous, with a very slight pallial sinus and smooth margins; hinge line with about six teeth on

either side of a well-developed resilium, the most anterior tooth of all a little more distant and notably larger than any of the others. Length, 1.7; alt. 1.2; max. diam. 1.0 mm. (Dall).

Yoldia (Yoldiella) indolens Dall.

Yoldie[a] (*Yoldiella*) *indolens* Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1898, p. 381. U. S. S. *Albatross* station 2784, "on the southern coast of Chile, in 194 fathoms, mud, bottom temperature 51°.9 F." Also at station 2785, in 122 fathoms.

Type Locality: Southern coast of Chile, in 194 fathoms, mud. Type No. 122,740 U. S. Nat. Mus.

Range: Southern coast of Chile.

Apparently no illustration has been given of this species. According to Dall it resembles *Yoldia chilenica* but is more inflated. Hinge with about a dozen teeth on each side of the pit for the resilium.

Yoldia (Yoldiella?) infrequens Dall.

Yoldia (*Yoldiella?*) *infrequens* Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 381. U. S. S. *Albatross* station 2784, "in 194 fathoms, mud, off the coast of southern Chile, bottom temperature 51°.9 F." Also at station 2783, in 122 fathoms.

Type Locality: Off the coast of southern Chile, in 194 fathoms, mud. Type No. 110,692 U. S. Nat. Mus.

Range: Off the southern coast of Chile.

Shell very small, callistaeform, tumid; both ends of shell evenly rounded; concentrically striated; hinge with about 9 anterior and 13 posterior teeth. Length, 4.4 mm.; height, 3.5 mm.; maximum diameter, 2.0 mm.

Yoldia (Yoldiella) leonilda Dall.

Yoldia (*Yoldiella*) *leonilda* Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 382. U. S. S. *Albatross* station, 3360, "Gulf of Panama, in 1672 fathoms, sand, bottom temperature 42° F."

Yoldia leonilda Dall, Zetek, *Rev. Nueva*, Nos. 1 & 2, 1918, p. 38. Panama.

Type Locality: Gulf of Panama, in 1,672 fathoms, sand. Type No. 122,909 U. S. Nat. Mus.

Range: Gulf of Panama.

Shell small, oval, smooth, white; hinge with 12 anterior and 14 posterior teeth.

Yoldia (Yoldiella?) mantana Dall.

Yoldia (*Yoldiella?*) *mantana* Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 381. U. S. S. *Albatross* station 2792, "in 401 fathoms, mud, off Manta, Ecuador, bottom temperature 42°.9 F."

Type Locality: Off Manta, Ecuador, in 401 fathoms, mud. Type No. 122,756 U. S. Nat. Mus.

Range: Known only from the type locality.

Shell small, elongate-oval, white, nearly equilateral, with a pale yellowish periostracum; surface mostly smooth but with a few irregular concentric striae; hinge with about 9 anterior and 10 or 11 posterior teeth. Length, 5.0 mm.; height, 3.2 mm.; maximum diameter, 2.5 mm.

Genus **Cyrilla** A. Adams.

Huxleyia A. Adams, *Ann. & Mag. Nat. Hist.*, Ser. 3, Vol. 5, April, 1860, p. 303. Sole species: *Huxleyia sulcata* A. Adams. See also p. 432.

Not *Huxleyia* Bowerbank. Dall (1898), cited the use of the name *Huxleyia* by Bowerbank but we have not noticed a citation to the original reference.

Not *Huxleya* Dyster, *Quart. Jour. Micr. Soc.*, Vol. 6, 1858, p. 260.

Cyrilla A. Adams, *Ann. & Mag. Nat. Hist.*, Ser. 3, Vol. 5, June, 1860, p. 478. "In a former paper I gave the name *Huxleyia* to a new genus of bivalve Mollusca. Should, however, this name have been already used, which is not improbable, *Cyrilla* might be substituted for it." ———A. Adams, *Ann. & Mag. Nat. Hist.*, Ser. 3, Vol. 9, 1862, p. 295. ———A. Adams, *Journ. de Conchyl.*, Vol. 16, 1868, p. 41. ———Dall, *Trans. Wagner Free Inst. Sci.*, Vol. 3, Pt. 4, 1898, p. 601. Type: *H. sulcata* A. Adams.

Type (by monotypy): *Huxleyia sulcata* A. Adams. [*Ann. & Mag. Nat. Hist.*, Ser. 3, Vol. 5, 1860, p. 303. "*Hab.* 16 miles from Mino-Sima, Straits of Korea; dredged from 63 fathoms." ———A. Adams, *Journ. de Conchyl.*, Vol. 16, 1868, p. 42, pl. 4, fig. 2. Original locality cited.

Shell suborbicular, minute, exteriorly smooth or with simple sculpture; pallial line entire; fossette for ligament enlarged and rounded; anterior cardinal teeth reduced, posterior series of teeth well developed; interior of shell not nacreous.

Nucinella Wood[85] with the type *Nucula miliaris* Deshayes from the Eocene of the Paris Basin, is a related genus. The name *Pleurodon* Wood was replaced by *Nucinella* Wood due to the earlier use of *Pleurodon* by Harlan. *Pleurodon microdus* Boettger, *P. cinctus* von Koenen, *P. dobergensis* Lienenklaus and *P. zinndorfi* Zilch[86] all referred to *Pleurodon*, have been described from the Oligocene of Germany and the genus has been cited from Eocene to Recent. *Pleurodon gunteri* Mansfield[87] has been described from the Miocene, and *P. woodii* Dall[88] from the Miocene and Pliocene of Florida, and *P. adamsii* occurs in the waters off the coast of Florida. E. A. Smith[89] recorded a species living off the Cape of Good Hope, under the name of *Nuculina ovalis* Wood. It is probably a distinct species from the one originally described under that name from the Crag, Pliocene of England. Jeffreys[90] cited *Nucinella ovalis* Wood from the Strait of Korea in 40 fathoms but probably that record can be referred to some similar species inhabiting the North Pacific. Lamy described "*Nucinella Serrei*"[91] from Brazil, and Cotton & Godfrey have recently added a new species, "*Pleurodon hedleyi*," to the fauna of South Australia. Species of *Cyrilla* are also known off the coasts of New Zealand[92] and Japan as well as off North and Central America.

[85] *Nucinella* Wood, *Palaeontogr. Soc., Monogr. Crag. Moll.*, Pt. 2, 1850, p. 72. Species cited: *Nucula miliaris* Deshayes. In the synonymy of which was included *Pleurodon ovalis* S. Wood, 1840. *Nucinella* to replace *Pleurodon* Wood, 1840 [not *Pleurodon* Harlan, *Jour. Acad. Nat. Sci. Philadelphia*, Vol. 6, 1831, p. 284]. ———Schenck, *Jour. Paleo.*, Vol. 13, no. 1, January, 1939, p. 39. "*Nucinella* Wood, 1850 (genotype, *N. miliaris* (Deshayes), from the Eocene of the Paris Basin)" [=*Nucula miliaris* Deshayes, Descript. Coq. Foss. env. Paris, Vol. 1, Livr. 15, 1829, p. 235, pl. 36, figs. 7, 8, 9].

[86] *Pleurodon zinndorfi* Zilch, *Arch. f. Molluskenkunde*, Bd. 69, No. 5-6, November, 1937, p. 250, figs. 1a, 1b. "In den mitteloligozänen Meeressanden des Mainzer Beckens, am Welschberg bei Waldböckelheim."

[87] *Pleurodon gunteri* Mansfield, *Florida State Geol. Surv., Bull.* No. 8, 1932, p. 38, pl. 2, figs. 4 and 6. Vaughan Creek, Walton County, Florida. Upper Middle Miocene.

[88] *Pleurodon woodii* Dall, *Trans. Wagner Free Inst. Sci.*, Vol. 3, pt. 4, 1898, p. 600, pl. 24, fig. 10. "Pliocene marls of the Caloosahatchie, Florida." ———Mansfield, *Florida State Geol. Surv., Bull.* No. 8, 1932, p. 37, pl. 2, figs. 1 and 3. *Cancellaria* zone—borrow pit, Jackson Bluff, Leon County, Florida; upper Miocene.

[89] *Nuculina ovalis* (S. Wood), E. A. Smith, Sci. Rept. Voy. Challenger, Zool., Vol. 13, 1885, p. 230, pl. 19, figs. 1, 1b. "Simon's Bay, Cape of Good Hope, in 15 to 20 fathoms."

[90] Jeffreys, J. G., *Jour. Linn. Soc. London*, Vol. 14, 1879, p. 420.

[91] *Nucinella serrei* Lamy, *Bull., Mus. Nat. d'Hist. Nat. (Paris)*, Vol. 18, no. 7, 1912, p. 432, figs. 1, 2, 3. Brazil.

[92] *Pleurodon maorianus* Hedley, *Rec. Australian Mus.*, Vol. 5, no. 2, January 28, 1904, p. 87, fig. 14. "from 5 fathoms off Anchor Island, Dusky Sound, New Zealand."

Two generic names *Cyrillona* and *Cyrillista* have been proposed by Iredale[93] for austral species formerly referred to *Cyrilla* or *Nuculina*. *Diabolica* Jousseaume[94] is referable to *Cyrilla* as indicated by Thiele.

Lamy[95] has reviewed many of the species referred to *Pleurodon* and *Nucinella*.

KEY TO THE SPECIES OF *Cyrilla*.

A. Lateral tooth short, ligamentary pit large.....*munita*
B. Lateral tooth long, ligamentary pit small.....*subdolus*

Cyrilla munita Carpenter in Dall.

Cyrilla munita Carpenter, Dall, *Trans. Wagner Free Inst. Sci.*, Vol. 3, pt. 4, April. 1898. p. 602. "From thirty fathoms off Catalina Island, California." ———Dall, *U. S. Nat. Mus.*, *Bull.* 112, 1921, p. 14 (under the genus *Pleurodon*). Santa Barbara Islands to the Gulf of California. ———Schenck, *Jour. Paleo.*, Vol. 13, no. 1, January, 1939, p. 39, pl. 6, figs. 14 and 15. Type localities of *Cyrilla munita* and *Nucula petriola* cited.

Nucula petriola Dall, *Proc. U. S. Nat. Mus.*, Vol. 52, December 27, 1916, p. 395. "Off Santa Rosa Island, California, in 53 fathoms, mud." ———I. S. Oldroyd, *Stanford Univ. Publ. Univ. Ser. Geol. Sci.*, Vol. 1, 1924, p. 12. Type locality cited.

Nuculina munita Carpenter, Lamy, *Bull. Mus. Nat. d'Hist. Nat.* (*Paris*), Vol. 18, no. 7, 1912, pp. 430, 431. Earlier records cited.

Pleurodon munitum (Carpenter) Dall, I. S. Oldroyd, *Stanford Univ. Publ. Univ. Ser. Geol. Sci.*, Vol. 1, 1924, p. 36. Locality and range same as cited by Dall.

Nucinella munita [Carpenter in Dall], Keen, Check List West North Amer. Mar. Moll., (Stanford Univ., Calif.), 1937, p. 23, Lat. 23°-34° N.

Type Locality: Off Catalina Island, California, in 30 fathoms. Type of *Nucula petriola*, No. 271,416 U. S. Nat. Mus.

Range: Santa Rosa Island, California to ? Lat. 34° S.

A small rounded-quadrate shell with a large fossette.

Subgenus **Neopleurodon** Hertlein & Strong, nov.

Type: *Pleurodon subdolus* Strong & Hertlein.

Shell minute, suborbicular; exteriorly smooth or with simple sculpture; pallial line entire; hinge plate well developed with teeth forming a gentle arc; a long lateral tooth present in right valve; interior not nacreous.

Neopleurodon differs from *Cyrilla* in the more even arcuate series of teeth and in the very small area for the ligament, and longer lateral tooth.

Judging from the illustration, *Pleurodon ovalis* Wood[96] from the Pliocene of England may belong to this subgenus, as may *"Pleurodon hedleyi"* Cotton & Godfrey[97].

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93 Iredale, T., *Rec. Australian Mus.*, Vol. 17, no. 4, September 4, 1929, pp. 160, 188. *Cyrillona*, "Type *Cyrilla dalli* Hedley." *Mem. Australian Mus.*, Mem. 4, Vol. 1, pt. 5, July 29, 1902, p. 296, fig. 44. "off Port Kembla, in 63-75 fathoms, and off Cape Three Points in 41-50 fathoms." *Cyrillista*, "Type *Nuculina concentrica* Verco." Illustrated by Cotton & Godfrey, Moll. South Australia, Pt. 1, 1938, p. 56, fig. 38.

94 *Diabolica diabolica* Jousseaume, *Le Naturaliste*, Ann. 19, (Ann. 11, Ser. 2), no. 257, November 15, 1897, p. 265. Sole species: *Diabolica diabolica* Jousseaume. No locality cited. ———Lamy, *Mem. Inst. Egypt*, Vol. 37, 1938, p. 8, fig. 1 (as *Nucinella* (*Cyrilla*) *diabolica*). Gulf of Akaba.

95 Lamy, E., Sur le Genre Pleurodon ou Nucinella S. Wood, avec description d'une espèce nouvelle. *Bull. Mus. Nat. d'Hist. Nat.* (*Paris*), Vol. 18, no. 7, 1912, pp. 429-433. See also Lamy, E., Journ. de Conchyl., Vol. 60, no. 2, December 15, 1912, pp. 108, 109 (footnote).

96 *Pleurodon ovalis* Wood, *Mag. Nat. Hist.*, New Ser., Vol. 4, 1840, p. 230, Suppl. pl. 13, fig. 1. "Coralline crag Ramsholt and Sutton." ———See illustration by Wood, Palaeontogr. Soc., Monogr. Crag. Moll., Pt. 2, 1850, p. 72, pl. 10, figs. 4a, 4b, 4c.

97 *Pleurodon hedleyi* Cotton & Godfrey, Moll. South Australia, Pt. 1. Handbook Flora and Fauna of South Australia, issued by South Australian Brit. Sci. Guild, Adelaide, 1938, p. 57, fig. 39. "100 fathoms, 40 miles south of Cape Wiles, South Australia."

Cyrilla (Neopleurodon) subdolus Strong & Hertlein.

Pleurodon subdolus Strong & Hertlein, *Proc. Calif. Acad. Sci.*, Ser. 4, Vol. 22, no. 6, December 31, 1937, p. 162, pl. 35, figs. 14, 18, 19. "Lat. 23° 12′ N., Long. 106° 29′ W., dredged in 12 fathoms, about five miles west of Mazatlan, Sinaloa, Mexico."

Type Locality: Off Mazatlan, Mexico, in 12 fathoms. Type No. 6,970 Calif. Acad. Sci. Paleo. Type Coll.

Range: Known only from the type locality.

The more regularly oval shell, persistant dark epidermis, and different hinge are features separating *Cyrilla subdolus* from *C. munita* (Carpenter) Dall. *Cyrilla adamsi* Dall[98] from the Straits of Florida is a somewhat similar species but the hinge is different.

Genus **Malletia** Desmoulins.

Malletia Desmoulins, *Act. Soc. Linn. Bordeaux*, Vol. 5, February 15, 1832, p. 85. ———Stoliczka, *Mem. Geol. Surv. India. Palaeont. Indica.* Cret. Fauna South. India, Vol. 3, 1871, pp. XX, 321. "Type, *M. chilensis*, Desm." ———Verrill & Bush, *Amer. Jour. Sci.*, Ser. 4, Vol. 3, January, 1897, p. 56. "Type *Malletia chilensis* Desmoulins." ———Verrill & Bush, *Proc. U. S. Nat. Mus.*, Vol. 20, 1898, p. 873. Type: *Malletia chilensis* Desmoulins. ———Dall, *Trans. Wagner Free Inst. Sci.*, Vol. 3, pt. 4, 1898, p. 581. "Type *M: norrisii* (Sby.)=*M. chilensis* Desm." ———Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 383. Type: *M. chilensis* Desmoulins. ———Cossmann & Peyrot, *Act. Soc. Linn. Bordeaux*, Vol. 66 (Conch. Neog. Aquit., Vol. 2, Livr. 1), 1912, p. 121. Genotype: *M. chilensis* Desmoulins. ———Grant & Gale, *Mem. San Diego Soc. Nat. Hist.*, Vol. 1, 1931, p. 132. Type: *M. chilensis* Desmoulins. ———Prashad, Siboga Exped., Mon. 53c, Lamell., 1932, p. 25. Type: *Malletia chilensis* Desmoulins.

Solenella Sowerby, *Proc. Zool. Soc. London*, for 1832 (issued March 13, 1833), p. 197. Sole species: *Solenella norrisii*. Valparaiso, Chile, in soft mud, at from 14 to 45 fathoms.

Pseudomalletia Fischer, Man. de Conchyl., 1886, p. 987. Species cited: *P. obtusa* Sars and *P. transversa* Ponzi.

Type (designated by Stoliczka): *Malletia chilensis* Desmoulins.

Shell oval, compressed, smooth or concentrically furrowed, epidermis olive; ligament external, elongated, prominent; hinge with an anterior and posterior series of fine sharp teeth; interior subnacreous; pallial sinus large and deep; anterior adductor scar giving off a long oblique pedal line (Tryon: Struct. and Syst. Conch.)

The shell of *Malletia* s.s. is oblong elliptical, blunt posteriorly and without a definite rostrum or carination. The carinated and rostrate species with strong concentric sculpture can in many cases be referred to *Neilo* H. & A. Adams. The absence of a lunule, escutcheon and distinct rostrum serve to separate *Malletia* from *Yoldia*. A characteristic feature of the hinge of *Malletia* is that the posterior series of teeth are often more than twice as numerous as the anterior series.

Malletia has been recorded from upper Cretaceous[99] to Recent. It is primarily a Magellanic genus which is said to have reached the northern

[98] *Pleurodon adamsi* Dall, *Trans. Wagner Free Inst. Sci.*, Vol. 3, pt. 4, April, 1898, p. 601, pl. 24, fig. 9. "Dredged seven miles east of Fowey Rocks, Straits of Florida."

[99] *Malletia gracilis* Wilckens, Wiss. Ergeb. Schwed. Südpolar-Exped., 1901-1903, Bd. 3, Lief. 12, 1910, p. 25, Taf. 2, fig. 4. Seymour Island, Antarctica; Cretaceous. The shape of this species is similar to that of *M. chilensis* Desmoulins.

Malletia ornata Sowerby has been reported from Patagonia in beds referred to the upper Cretaceous, also in beds referred to the Eocene by von Ihering (*An. Mus. Nac. Buenos Aires*, Ser. 3, Vol. 7, 1907, pp. 4, 228). The species bears a resemblance to *M. australis* Quoy & Gaimard of New Zealand. Powell (Shellfish of New Zealand, 1937, p. 55), referred *M. australis* to *Neilo* which he considered to be of generic status.

hemisphere during the Oligocene or Miocene, but the genus appears to be present in the Eocene of California.

One of the largest species of *Malletia* is *M. gigantea*[100] which occurs at Kerguelen Island in the south Atlantic. The size is noteworthy, the type specimen is 62 mm. in length. The posterior end of *M. gigantea* is expanded in a manner somewhat resembling *Yoldia thraciaeformis*. E. A. Smith mentioned that the animal of *Yoldia subaequilateralis*[101] "resembles that of *Solenella gigantea* in all respects excepting that the edge of the foot is bluntly serrated or scalloped."

Malletia (Malletia) chilensis Desmoulins.

Malletia chilensis Desmoulins, *Act. Soc. Linn. Bordeaux*, Vol. 5, January 15, 1832, p. 85, pl. 1, figs. 1-8. Valparaiso, Chile, in 14 to 45 fathoms (according to Dall). ———H. & A. Adams, Gen. Rec. Moll., Vol. 2, 1858, p. 549, pl. 126, figs. 6, 6a. ———Chenu, Man. de Conchyl., Vol. 2, 1862, p. 181, fig. 913. ———Kobelt, Illustr. Conchylienbuch, Bd. 2, Lief. 10-11, 1881, p. 372, pl. 109, fig. 3. Chile. ———Tryon, Struct. and Syst. Conch., Vol. 3, 1884, p. 249, pl. 126, fig. 34 (on expl. to pl. 126 as *Yoldia* (*Malletia*) *chilensis*). Valparaiso, Chile. ———Fischer, Man. de Conchyl., Fasc. 10, 1886, p. 987, pl. 17, fig. 22. ———Verrill & Bush, *Amer. Jour. Sci.*, Ser. 4, Vol. 3, 1897, p. 56, fig. 9 (on p. 60). ———Stempell, *Zool. Jahrb.*, Suppl. Bd. 4 (Fauna chilensis, Bd. 1), Heft 2, July 1, 1898, p. 343 (and following pages), pl. 22, figs. 2, 3, 4, 9, 12; pl. 23, figs. 13, 14, 15, 16, 17; pl. 24, fig. 32 (anatomy). ———Stempell, *Zool. Jahrbuch.*, Suppl. Bd. 5 (Fauna Chilensis, Bd. 2), 1902, p. 219. Harbor of Coquimbo; Talcahuano, in 10 fathoms; Calbuco, in 10 fathoms. ———Dall, *Proc. U. S. Nat. Mus.*, Vol. 37, 1909, p. 251. Coquimbo, south to Talcahuano Bay, Chile. ———Heath, *Mem. Mus. Roy. d'Hist. Nat. Belg.*, Ser. 2, Fasc. 10, 1937, p. 5, pl. 10, fig. 87 (Anatomy). Talchano [?Talcahuano], Chile.

Solenella norrisii Sowerby, *Proc. Zool. Soc. London* for 1832 (issued March 13, 1833), p. 197. "*Hab.* ad Valparaiso." "Discovered by Mr. Cuming, in soft mud, at from fourteen to forty-five fathoms depth." ———Sowerby, Gen. Shells, Vol. 2, pl. 237 (four figs.), ?1833. "Dredged by Mr. H. Cuming at Valparaiso." ———Reeve, Conch. Syst., Vol. 1, 1841, p. 48, pl. 30, figs. 1-4. ———Hanley, Cat. Rec. Biv. Shells, p. 17, 1843, p. 337, 1856?, Suppl. 10, figs. 8, 1843. ———d'Orbigny, Voy. Amér. Mérid., Vol. 5, 1846, p. 543. Dredged in 10 fathoms in the Bay of Valparaiso, Chile. ———Woodward, Man. Moll., 1851-1856, p. 270, pl. 17, fig. 22. Ed. 2, 1868, p. 429, pl. 17, fig. 22. Reprint of Ed. 4 (1880), 1910, p. 429, pl. 17, fig. 22. Valparaiso, Chile. ———Hupé, Hist. de Chile, Zool., Vol. 8, 1854, p. 306. Various parts of the coast of Chile. ———Deshayes, Traite Elem. Conchyl., Vol. 2, 1839-1857 [-1858], p. 270, pl. 34, figs. 5, 6, 7. Valparaiso, Chile. ———Hanley, Thes. Conch., Vol. 3, 1860, p. 164, pl. 226 (*Nuculidae* pl. 1), figs. 1 and 2. Valparaiso, Chile.

Solenella norrisii Sowerby var. *brevior* Hanley, Thes. Conch., Vol. 3, 1860, p. 164, pl. 226 (*Nuculidae*, pl. 1). Valparaiso, Chile.

Type Locality: Valparaiso, Chile, in 14 to 45 fathoms, mud.

Range: Coquimbo to Talcahuano Bay, Chile.

Shell subovate, somewhat compressed, with polished olivaceous epidermis; beaks anterior to the middle; unornamented except by lines of growth; hinge with teeth very fine and very numerous posteriorly but very few anteriorly.

100 *Solenella gigantea* E. A. Smith, *Ann. & Mag. Nat. Hist.*, Ser. 4, Vol. 16, 1875, p. 72. "*Hab.* Royal Sound, Kerguelen's Island." ———E. A. Smith, *Phil. Trans. Roy. Soc. London*, Vol. 168, 1879, p. 187, pl. 9, fig. 19. Royal Sound, both at Observatory Bay and near the eastern shore of Swain's Harbour, on mud in about 10 fathoms.

Malletia gigantea E. A. Smith, E. A. Smith, Sci. Res. Voy. Challenger, Zool., Vol. 13, Lamell., 1885, p. 244. Betsy Cove, Kerguelen Island, in shallow water; also at Balfour Bay, in 20 to 60 fathoms. ———Lamy, *Bull. Mus. Nat. d'Hist. Nat.* (*Paris*), Vol. 12, 1906, p. 203. Kerguelen Islands. ———Lamy, *Bull. Mus. Nat. d'Hist. Nat.* (*Paris*), Vol. 21, no. 2, 1915, p. 76. Several localities in Kerguelen Islands.

101 *Yoldia subaequilateralis* E. A. Smith, *Ann. & Mag. Nat. Hist.*, Ser. 4, Vol. 16, 1875, p. 73. "*Hab.* Swain's Bay, Kerguelen's Island." ———E. A. Smith, *Phil. Trans. Roy. Soc. London*, Vol. 168, 1879, p. 187, pl. 9, fig. 18. Swain's Bay. Dredged in 7-10 fathoms in very sheltered water.

Subgenus **Neilo** H. & A. Adams.

Neilo A. Adams, *Proc. Zool. Soc. London,* 1852, p. 93. Sole species: *Neilo cumingii* A. Adams. "It is from the shores of New Zealand." ———H. & A. Adams, Gen. Rec. Moll., Vol. 2, 1858, p. 549. ———Verrill & Bush, *Amer. Jour. Sci.,* Ser. 4, Vol. 3, 1897, p. 57. Type: *N. cumingii* Adams. ———Verrill & Bush, *Proc. U. S. Nat. Mus.,* Vol. 20, 1898, p. 877. Type: *Neilo cumingii* Adams. ——— Dall, *Trans. Wagner Free Inst. Sci.,* Vol. 3, pt. 4, 1898, p. 581. Type: *N. australis* Quoy & Gaimard (+*N. cumingii* A. Adams). ———Suter, Man. New Zealand Moll., 1913, p. 837. Type: *N. cumingii* A. Adams =*australis* Quoy & Gaimard.

Type (by monotypy): *Neilo cumingii* A. Adams. [*Proc. Zool. Soc. London,* 1852, p. 93. "It is from the shores of New Zealand." ———H. & A. Adams, Gen. Rec. Moll., Vol. 2, 1858, p. 549, pl. 126, figs. 7, 7a, 7b. ——— Chenu, Man. de Conchyl., Vol. 2, 1862, p. 181, fig. 914. ———Suter, Man. New Zealand Moll., 1913, p. 837, pl. 58, figs. 2, 2a (as *Malletia australis* Quoy & Gaimard). New Zealand].

The subgenus *Neilo* differs from *Malletia* in the ark-like form and in that the surface of the valves is usually ornamented by concentric sculpture.

Neilo has been recorded from late Cretaceous to Recent in Patagonia, from the Helvetian, Miocene, of France, and from upper Oligocene to Recent in New Zealand. The species described as *Nucula abrupta* by Conrad from the Miocene of Astoria, Oregon, was later referred to *Neilo,* but, there is some doubt as to the generic assignment of the species. One species assigned to *Neilo* has been described from deep water off tropical western North America.

Spineilo Finlay & Marwick[102], with the type *Malletia elongata* Marshall from the Wangaloan (Danian) of New Zealand, was proposed as a subgenus of *Neilo,* the latter considered by them as of generic status.

Malletia (Neilo) goniura Dall.

Malletia goniura Dall, *Proc. U. S. Nat. Mus.,* Vol. 12, 1889, p. 251, pl. 10, fig. 10. U. S. Fish Commission station 2793, "off the coast of Ecuador in 741 fathoms, mud; bottom temperature 38°.4 F."

Malletia (*Nelro*) [typ. error for *Neilo*] *goniura* Dall, Dall, *Bull. Mus. Comp. Zool.,* Vol. 43, no. 6, October, 1908, p. 386, pl. 18, fig. 6. U. S. S. *Albatross* station 3360. Gulf of Panama, in 1672 fathoms, sand, bottom temperature 42° F. Also original locality cited.

Type Locality: Off the coast of Ecuador, in 741 fathoms, mud.

Range: Gulf of Panama to off the coast of Ecuador, in deep water.

This is a thin fragile shell on which two ridges radiate from the beak to the truncate posterior margin. Hinge of type described as possessing 19 anterior and 25 posterior teeth. Another specimen described by Dall from the Gulf of Panama apparently had 14 anterior and over 30 posterior teeth.

Subgenus ***Minormalletia*** Dall.

Minormalletia Dall, *Bull. Mus. Comp. Zool.,* Vol. 43, no. 6, October, 1908, p. 385. Sole species: *Malletia* (*Minormalletia*) *arciformis* Dall.

Type (by monotypy): *Malletia* (*Minormalletia*) *arciformis* Dall.

Shell small, blunt, plump, with amphidetic ligament, no resilium, the pallial sinus large, no radial depressions or sculpture (Dall).

Marwick[103] has recorded *Minormalletia* from the medial Tertiary of New Zealand.

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[102] *Spineilo* Finlay & Marwick, *Geol. Surv. New Zealand, Palaeo. Bull.* No. 15, May 20, 1937, p. 17. "Genotype: *Malletia elongata* Marshall, Wangaloan (Danian), New Zealand," p. 17, pl. 1, figs. 4 and 5. "Wangaloa (Type), common; Boulder Hill, common." Danian, upper Cretaceous.

[103] Marwick, J., *Geol. Surv. New Zealand, Palaeo. Bull.* No. 13, 1931, p. 55.

Malletia (Minormalletia) arciformis Dall.

Malletia (*Minormalletia*) *arciformis* Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 385, pl. 15, figs. 5 and 6. U. S. S. *Albatross*, station 3417, "off Acapulco, Mexico, in 493 fathoms, mud, bottom temperature 40°.6 F."

Type Locality: Off Acapulco, Mexico, in 493 fathoms, mud.

Range: Known only from the type locality.

The pallial sinus is notable in that the greater part of its basal scar is identical with the pallial line itself, whereas in most of the Malletinae the sinus tends to slope obliquely upward (Dall).

Dall pointed out that the profile of this species, although more rounded below and behind, is somewhat similar to that of *Arca adamsii* (Shuttleworth (MS)) E. A. Smith, a Caribbean species.

Malletia (Minormalletia) benthima Dall.

Malletia (*Minormalletia*) *benthima* Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 386, pl. 15, figs. 1 and 2. U. S. S. *Albatross* station 3417, "off Acapulco, Mexico, in 493 fathoms, mud, bottom temperature 40°.6 F."

Type Locality: Off Acapulco, Mexico, in 493 fathoms, mud. Type No. 122,927 U. S. Nat. Mus.

Range: Known only from the type locality.

Shell small, thin, very inequilateral; hinge with 12-13 anterior and 17-18 posterior teeth.

The subgeneric position of the following species of *Malletia* is uncertain.

Malletia faba Dall.

Malletia faba Dall, *Nat. Hist. Soc. Brit. Columbia, Bull.* No. 2, January, 1897, p. 10, pl. 2, fig. 10. "Off Sea Lion Rock, coast of Washington, in 477 fms.; off Queen Charlotte Islands, British Columbia, in 876 fms.; off Tillamook in 786 fms.; off San Diego, Cal., in 822 fms., U. S. Fish Commission." ———Dall, Checklist Rec. Bivalve Moll., (Southwest Museum), 1916, p. 13. Queen Charlotte Islands, Brit. Columbia, to Lower California. ———Dall, *U. S. Nat. Mus., Bull.* 112, 1921, p. 14. Queen Charlotte Islands, British Columbia, to Lower California. ———I. S. Oldroyd, *Stanford Univ. Publ. Univ. Ser. Geol. Sci.*, Vol. 1, 1924, p. 37, pl. 13, fig. 16. Range same as cited by Dall. ———Keen, Check List West North Amer. Mar. Moll., (Stanford Univ. Press), 1937, p. 22. Range: Lat. 30°-54° N.

Type Locality: Off Sea Lion Rock, Washington, in 477 fathoms. Type No. 122,569 U. S. Nat. Mus.

Range: Queen Charlotte Islands, British Columbia, to Lower California.

Shell thin, ovate, inflated, smooth, slightly inequilateral; hinge with about 9 small posterior and about 32 anterior teeth.

Malletia inequalis Dall.

Malletia inequalis Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 383. U. S. S. *Albatross* station 2772, "off Cape Virgins, in 31 fathoms, sand, and 2778, Straits of Magellan, in 61 fathoms, mud, bottom temperature 47°.9 F."

Type Locality: Off Cape Virgins, in 31 fathoms, sand, and Straits of Magellan, in 61 fathoms, mud. [Type locality here designated as off Cape Virgins, in 31 fathoms, sand].

Range: Off Cape Virgins, and Straits of Magellan.

The truncation behind, the coalescent pallial sinus, and the compressed form separate it from the other species (Dall). Hinge with 3 anterior and 24 posterior teeth.

Malletia magellanica E. A. Smith.

Malletia magellanica E. A. Smith, *Proc. Zool. Soc. London*, 1881, p. 39, pl. 5, figs. 3, 3a. "*Hab.* Station 3, Mayne Harbour, 9 fathoms, greenish mud; and Cockle Cove, 2-32 fathoms, mud." ———Mabille & Rochebrune, Miss. Sci. Cap. Horn, Moll., Vol. 6, Zool., Pt. 2, 1889, p. H 114. Mayne Harbor; Cockle Cove (E. Smith).

Type Locality: Mayne Harbor and Cockle Cove, Chile.

Range: Straits of Magellan and Magellanic region.

Malletia patagonica Mabille & Rochebrune.

Malletia patagonica Mabille & Rochebrune, Miss. Sci. Cap. Horn, Vol. 6, Zool., pt. 2, 1889, p. H 114, pl. 8, fig. 1. "Hab. ———Punta-Arenas."

Malletia hyadesi Mabille & Rochebrune, Miss. Sci. Cap. Horn, Vol. 6, Zool., pt. 2, 1889, p. H 114. "Hab. ———Punta-Arenas."

Malletia magellanica Mabille & Rochebrune, Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 383 (at least in part). Punta Arenas. Also off Cape Virgins, in 31½ fathoms, and Magellan Straits, in 77 fathoms.

Not *Malletia magellanica* E. A. Smith.

Type Locality: Punta Arenas, Chile.

Range: Southern Chile in the Magellanic region.

Malletia peruviana Dall.

Malletia peruviana Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 384, pl. 10, figs. 3 and 5. U. S. S. *Albatross* station 4654, "N. 68° W., twenty-four miles from Aguja Point, Peru, in 1036 fathoms, mud, bottom temperature 37°.3 F."

Type Locality: Twenty-four miles N. 68° W., from Aguja Point, Peru, fathoms, ooze. Type No. 122,906 U. S. Nat. Mus.

Range: Known only from the type locality.

This species is remarkable for its almost blackish color and extremely shallow pallial sinus, which does not extend in front of the posterior adductor scar; the anterior end is unusually short and almost pointed (Dall). Hinge with about 10 anterior and 33 posterior teeth.

Malletia truncata Dall.

Malletia truncata Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 384, pl. 17, fig. 1. U. S. S. *Albatross* station 3374, "southwest of Malpelo Island, Gulf of Panama, in 1823 fathoms, ooze, bottom temperature 36°.4 F." Also at station 3361, in 1471 fathoms, and station 3381, in 1772 fathoms.

Type Locality: Southwest of Malpelo Island, Gulf of Panama, in 1,823 fathoms, ooze. Type No. 122,906 U. S. Nat. Mus.

Range: Known only from the type locality.

Remarkable for its light yellow color, its surface devoid of radial sculpture or indented margin, and its bluntly truncate posterior end. In the latter character and its subequal division of the hinge teeth it recalls *Neilo*, but is without the rostration of that form (Dall). Hinge with 20 anterior and about 27 posterior teeth.

Genus ***Tindaria*** Bellardi.

Tindaria Bellardi, Monogr. Nuculidi Terr. Terz. del. Piemonte e Liguria, 1875, p. 28. Sole species: *Tindaria arata* Bellardi. ———Verrill & Bush, *Proc. U. S. Nat. Mus.*, Vol. 20, 1898, p. 880. Type: *Tindaria arata* Bellardi. ———Dall, *Trans. Wagner Free Inst. Sci.*, Vol. 3, pt. 4, April, 1898, p. 581. Type: *T. arata* Bellardi. ———Sacco, Moll. Terr. Terz. Piemonte e Liguria, Pt. 26, December, 1898, p. 64. "(Tipo *T. arata* Bell.)." ———Cossmann & Peyrot, *Act. Soc. Linn. Bordeaux*, Vol. 66 (Conch. Neog. Aquit., Vol. 2, Livr. 1), 1912, p. 125. Genotype: *Tindaria arata* Bellardi. ———Woodring, *Carnegie Inst. Washington, Publ.* 366, 1925, p. 23. Type: *Tindaria arata* Bellardi.

Type (by monotypy): *Tindaria arata* Bellardi. [Mon. Nuculid. Terr. Terz. Piemonte e Liguria, 1875, p. 28, fig. 27. ———Sacco, Moll, Terr. Terz. Piemonte e Liguria, Pt. 26, December, 1898, p. 64, pl. 12, figs. 55, 56. Helvetian and Tortonian of Italy].

Shell small, veneriform, strongly inflated; beaks turned forward; sculptured by concentric rugae of varying development; ligament external, opisthodetic; hinge uninterrupted below umbo, posterior series of teeth strongly curved, the anterior series of teeth are heavier, shorter and straighter; pallial sinus moderately developed, narrowly triangular.

Tindaria is known from the Miocene of France and Italy and Miocene to Recent in the Caribbean region. It is not known to occur with certainty in the Tertiary of the western Americas but several species have been described from west American waters between Sitka, Alaska, and Cape Horn.

Subgenus ***Tindariopsis*** Verrill & Bush.

Tindariopsis Verrill & Bush, *Amer. Jour. Sci.*, Ser. 4, Vol. 3, 1897, p. 59. "Type *T. agathida* (Dall)."

Type (by original designation): *T. agathida* (Dall). [=*Malletia* (*Tindaria*) *agathida* Dall, *Proc. U. S. Nat. Mus.*, Vol. 12, 1889, p. 252, pl. 13, fig. 10. South from St. Kitts, in 687 fathoms, east from Tobago, in 880 fathoms].

This subgenus was proposed for species with ovate shells, with a short rostrum, defined by a radial ridge and a furrow.

Tindaria (Tindariopsis) sulculata Gould.

Nucula sulculata Couthouy, Gould, *U. S. Explor. Exped.*, Vol. 12, 1852, p. 424, Atlas, 1856, pl. 37, figs. 539a-e. Orange Harbor, Patagonia.

Leda sulculata Couthouy, Hanley, Thes. Conch., Vol. 3, 1860, p. 129 footnote. ———Mabille & Rochebrune, Miss. Sci. Cap. Horn. Vol. 6, Zool., Pt. 2, 1889, p. H 113. Cape Horn. Orange Bay. ———Stempell, *Sitzungsber. Kön. Preuss. Akad. Wiss. Berlin*, Jahrg. 1897, pp. 17-28. ———Stempell, *Zool. Jahrb.*, Bd. 4 (Fauna Chilensis, Bd. 1), Heft 2, July 1, 1898, p. 343 (and following pages), pl. 22, figs. 1, 5, 6, 7, 8, 10, 11; pl. 23, figs. 19, 21; pl. 24, figs. 23, 24, 25, 26, 28, 29, 30, 31; pl. 25, figs. 33, 34, 35, 36, 37, 38, 40, 41, 43 (anatomy).

Not *Lembulus sulculatus* Risso, Hist. Nat. Europ. Merid., Vol. 4, 1826, p. 320.

Leda lugubris A. Adams, *Proc. Zool. Soc. London*, 1856, p. 49. "Hab. . . . . ? Mus. Cuming." ———E. A. Smith, *Proc. Zool. Soc. London*, 1881, p. 39. Port Rosario in 2-30 fathoms; Wolsey anchorage, in 17 fathoms. ———Mabille & Rochebrune, Miss. Sci. Cap. Horn, Vol. 6, Zool., Pt. 2, 1889, p. H 113. Port Rosario (E. Smith).

Leda orangica Mabille & Rochebrune, Miss. Sci. Cap. Horn, Vol. 6, Zool., Pt. 2, 1889, p. H 113, pl. 8, fig. 3. "*Hab.* Baie Orange."

Tindaria (*Tindariopsis*) *sulculata* Gould, Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 390. Straits of Magellan. Also earlier records.

Type Locality: Orange Harbor, Chile.

Range: Cape Horn and Straits of Magellan.

The subgeneric position of the following species of *Tindaria* is uncertain.

Tindaria atossa Dall.

Tindaria atossa Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 388, pl. 15, figs. 3 and 4. U. S. S. *Albatross*, station 3392, "Gulf of Panama, in 1270 fathoms, hard bottom, temperature 36°.4 F." Also at station 3393, Gulf of Panama, in 1020 fathoms.

Type Locality: Gulf of Panama, in 1,270 fathoms, hard bottom. Type No. 122,920 U. S. Nat. Mus.

Range: Gulf of Panama.

Shell small, olivaceous, moderately polished, finely concentrically striated all over, with the beaks slightly anterior, the posterior end bluntly pointed, the anterior rounded; ligament small, amphidetic; anterior teeth six, posterior ten, the dorsal slopes gently, the basal margin roundly arcuate; interior white, margin entire. Measurements of the type: Length, 6.5 mm.; height, 4.5 mm.; maximum diameter, 3.0 mm. (From Dall).

Tindaria atossa resembles *T. panamensis* but the whole surface is sculptured and the posterior end is less elongated and pointed.

Tindaria compressa Dall.

Tindaria compressa Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 387, pl. 15, figs. 7 and 8; pl. 17, figs. 15 and 16. U. S. S. *Albatross* station 3360, "in 1672 fathoms, sand, bottom temperature 42° F." Also at station 3414, "southwest of the isthmus of Tehuantepec, in 2232 fathoms, green mud, bottom temperature 38°.5 F."

Type Locality: Lat. 6° 17′ 00″ N., Long. 82° 5′ 0″ W., in 1,672 fathoms, sand. Type No. 122,921 U. S. Nat. Mus.

Range: Southwest of the Isthmus of Tehuantepec to the Gulf of Panama, in deep water.

Shell small, thin, cythereiform, inequilateral, concentrically striated; hinge with 10-12 anterior and 21-25 posterior teeth.

Tindaria amabilis Dall[104] of the Antilles is a somewhat similar species.

Tindaria panamensis Dall.

Tindaria panamensis Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 388, pl. 17, figs. 10 and 12. U. S. S. *Albatross*, station 3392, "Gulf of Panama, in 1270 fathoms, hard bottom, temperature 36°.4 F."

Type Locality: Gulf of Panama, in 1,270 fathoms, hard bottom. Type No. 122,922 U. S. Nat. Mus.

Range: Known only from the type locality.

Surface with fine concentric threads which become much finer on the posterior third of the shell; hinge with 7 anterior and about 13 posterior teeth. Dimensions of type; length, 5.5 mm.; height, 4.3 mm.; maximum diameter 2.8 mm.

The more greenish color and dull surface of this species are said to be characteristic in comparison to similar species.

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[104] *Malletia* (*Tindaria*) *amabilis* Dall, *Bull. Mus. Comp. Zool.*, Vol. 18, June, 1889, p. 438, pl. 40, fig. 8. ———Dall, *Proc. U. S. Nat. Mus.*, Vol. 12, 1889, p. 252. In 607 fathoms, off St. Kitts, and in 880 fathoms east of Tobago.

Tindaria sp[105]., cited by Woodring from the Miocene of Bowden, Jamaica, is said to possess a similar shell but it is shorter and the posterior end is more inflated.

Tindaria mexicana Dall.

Tindaria mexicana Dall, *Bull. Mus. Camp. Zool.*, Vol. 43, no. 6, October, 1908, p. 389, pl. 17, figs. 11 and 14. U. S. S. *Albatross*, station 3418, "off the Mexican coast in 660 fathoms, sand, bottom temperature 39° F."

Type Locality: Off the Mexican coast, in 660 fathoms, sand. Type No. 122,925 U. S. Nat. Mus.

Range: Known only from the type locality.

Very similar to *T. smirna*, but with more prominent beaks; shorter and blunter, in proportion to height, and decidely less pointed and produced behind (Dall). Hinge with 11 anterior and about 21 posterior teeth.

Tindaria salaria Dall.

Tindaria salaria Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 387. "Dredged in Mid-Pacific, off Salar y Gomez Island, at U. S. S. *Albatross*, station 4693, in 1142 fathoms, manganese nodules, bottom temperature 35°.4 F."

Type Locality: Off Sala y Gomez, West of Chile, in 1,142 fathoms, manganese nodules.

Range: Known only from the type locality.

The shell of this species, in its general exterior characteristics, is said to resemble that of *Nucula proxima* Say.

Tindaria smirna Dall.

Tindaria smirna Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 389, pl. 17, figs. 6 and 7. U. S. S. *Albatross*, station 3360, "Gulf of Panama, in 1672 fathoms, sand, bottom temperature 42° F."

Type Locality: Gulf of Panama, in 1,672 fathoms, sand. Type No. 122,919 U. S. Nat. Mus.

Range: Known only from the type locality.

Shell small, polished, subtriangular, of a blackish olive tint; smooth over two thirds of the surface, but near the basal margin there are about 10 concentric grooves crossed by very fine radial striae; hinge with about 8 anterior and 12 posterior teeth. Length 5.5 mm.; height, 4.0 mm.; maximum diameter, 2.7 mm.

Close to *T. atossa*, but much more brilliantly polished, the shell shorter, more turgid, more nearly equilateral, and with the ligament distinctly and subequally amphidetic, while in *T. atossa* it appears, to the naked eye, to be entirely opisthodetic, though on opening the valves a small portion is seen to pass in front of the beaks (Dall).

Tindaria thea Dall.

Tindaria thea Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 390. U. S. S. *Albatross*, station 4654, "N. 68° W., twenty-four miles from Aguja Point, Peru, in 1036 fathoms, mud, bottom temperature, 37°.3 F."

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[105] *Tindaria* (*Tindaria*) sp., Woodring, *Carnegie Inst. Washington, Publ.* 366, May, 1925, p. 23, pl. 1, figs. 22, 23. Bowden, Jamaica; Miocene.

Type Locality: 24 miles northwest of Aguja Point, Peru, in 1,036 fathoms, mud. Type No. 110,577 U. S. Nat. Mus.

Range: Known only from the type locality.

Just about the color of dark, wet, tea-leaves after they have been steeped. Longer and more pointed, and more attenuated behind, than *T. smirna*, which has very similar sculpture but a more yellowish color. In looking from below, the series of hinge teeth seems uninterrupted, but the black color of the semi-internal resilium can be seen through the interstices, as it is situated above the tooth-line (Dall). Hinge with 8 anterior and 14 posterior teeth.

Tindaria virens Dall.

Malletia (*Tindaria*) *virens* Dall, *Proc. U. S. Nat. Mus.*, Vol. 12, 1889, p. 254, pl. 13, fig. 3. "In 122 to 449 fathoms, mud, on the west coast of Patagonia; temperatures 47° to 50° F."

Tindaria virens Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 389. Coast of Southern Chile and western Patagonia, in 122 to 449 fathoms.

Type Locality: West coast of Chile, in 122 to 449 fathoms, mud.

Range: Coast of southern Chile, in 122 to 449 fathoms.

Lighter colored, with alternating zones and with sharper and deeper concentric sulci, than those exhibited by *T. atossa* of the Panama fauna, which is the most nearly related species (Dall, 1908).

EXPLANATION OF THE PLATES.

Plate I.

Fig. 1. *Nucula* (*Nucula*) *declivis* Hinds. Length 5 mm., height 4 mm., thickness (both valves) 2.9 mm. Hypotype, left valve, from Station 203-D-1, dredged in 15 fathoms (27 meters), in Lat. 10° 56′ 05″ N., Long. 85° 49′ 25″ W., Port Parker, Costa Rica. P. 380.

Fig. 2. *Nucula* (*Nucula*) *declivis* Hinds. Length 4.8 mm., height 3.8 mm., thickness 1.6 mm. Hypotype, right valve, from Station 145-D-1, dredged in 13 fathoms (24 meters) in Lat. 26° 52′ N., Long. 111° 53′ W., Santa Inez Bay, east coast of Lower California. View of the interior. P. 380.

Fig. 3. *Nucula* (*Nucula*) *declivis* Hinds. Length 4.6 mm., width 3.4 mm., thickness (both valves) 2.7 mm. Hypotype, left valve, from the same locality as the specimen shown in Fig. 2. P. 380.

Fig. 4. *Nucula* (*Nucula*) *exigua* Sowerby. Length 5.7 mm., height 5.4 mm., thickness (both valves) 3.9 mm. Hypotype, left valve, dredged at Loc. 27595 (C.A.S.), San Bartolome (Turtle Bay), Lower California. P. 381.

Fig. 5. *Nucula* (*Nucula*) *exigua* Sowerby. View of posterior end of specimen shown in Fig. 4.

Fig. 6. *Nucula* (*Nucula*) *declivis* Hinds. View of posterior end of specimen shown in Fig. 1.

Fig. 7. *Nucula* (*Nucula*) *declivis* Hinds. View of specimen shown in Fig. 1 but with less magnification.

Fig. 8. *Nucula* (*Nucolopsis*) *schencki* Hertlein & Strong, sp. nov. Length 2.0 mm., height 1.7 mm., thickness (both valves), 1.0 mm. Holotype, left valve, from Station 195-D-9, dredged in 7 fathoms (12.6 meters), Lat. 15° 44′ 28″ N., Long. 96° 07′ 51″ W., Port Guatulco, Mexico. P. 384.

Fig. 9. *Nucula* (*Nucolopsis*) *schencki* Hertlein & Strong, sp. nov. Length 2.8 mm., height 2.5 mm. Paratype, right valve, from the same locality as the holotype shown in Fig. 8. View of the interior. P. 384.

Fig. 10. *Nucula* (*Nucolopsis*) *schencki* Hertlein & Strong, sp. nov. Dorsal view of the holotype shown in Fig. 8.

Fig. 11. *Nuculana* (*Saccella*) *acuta* Conrad. Length 8.6 mm., height 4.8 mm., thickness (both valves) 3.4 mm. Hypotype, left valve, dredged at a depth of two fathoms at Cedar Keys, Florida, H. Hemphill collector (Loc. 5710). P. 392.

Fig. 12. *Nuculana* (*Saccella*) *elenensis* Sowerby. Length 13.6 mm., height 7.0 mm., thickness (both valves) 5 mm. Hypotype, left valve, from Station 196-D-17, dredged in 23 fathoms (42 meters) in Lat. 15° 45′ N., Long. 96° 05′ 34″ W., Tangola-Tangola Bay, Mexico. P. 393.

Fig. 13. *Nuculana* (*Saccella*) *callimene* Dall. Length 14.5 mm., height 8.9 mm., thickness (both valves) 6.5 mm. Hypotype, left valve, from 3 miles south of Blanco Island, Gulf of Nicoya, Costa Rica. P. 393.

Fig. 14. *Nuculana* (*Saccella*) *elenensis* Sowerby. Length 16 mm., height 8.5 mm., thickness (both valves) 6.5 mm. Hypotype, left valve, from the same locality as the specimen shown in Fig. 2. P. 393.

Fig. 15. *Nuculana* (*Saccella*) *elenensis* Sowerby. Dorsal view of specimen shown in Fig. 14.

Fig. 16. *Nuculana* (*Saccella*) *elenensis* Sowerby. Length 13.3 mm., height 6.8 mm., thickness (both valves) 4.8 mm. Hypotype, left valve, from the same locality as the specimen shown in Fig. 12. P. 393.

Fig. 17. *Nuculana* (*Saccella*) *elenensis* Sowerby. Reproduction of figure of *Leda elenensis* Sowerby given by Hanley, Thes. Conch., Vol. 3, 1860, pl. 228 (*Nuculidae*, pl. 3), fig. 70. Panama.

Fig. 18. *Nuculana* (*Saccella*) *elenensis* Sowerby. Reproduction of figure of *Leda elenensis* Sowerby given by Hanley, Thes. Conch., Vol. 3, 1860, pl. 228 (*Nuculidae*, pl. 3), fig. 71. Panama.

Fig. 19. *Nuculana* (*Saccella*) *elenensis* Sowerby. Reproduction of figure of *Leda elenensis* Sowerby given by Hanley, Thes. Conch., Vol. 3, 1860, pl. 228 (*Nuculidae*, pl. 3), fig. 72. Panama.

Fig. 20. *Nuculana cuneata* Sowerby. Reproduction of figure of *Leda cuneata* Sowerby given by Hanley, Thes. Conch., Vol. 3, 1860, pl. 228 (*Nuculidae*, pl. 3), fig. 93. "Valparaiso." [Not the record "New Guinea!"]. Dorsal view. P. 403.

Fig. 21. *Nuculana cuneata* Sowerby. Reproduction of figure of *Leda cuneata* Sowerby given by Hanley, Thes. Conch., Vol. 3, 1860, pl. 228 (*Nuculidae*, pl. 3), fig. 92. Right valve. Same locality as cited for Fig. 20.

Fig. 22. *Nuculana* (*Saccella*) *elenensis* Sowerby. Length 15.5 mm., height 8.1 mm. Hypotype, left valve, from the same locality as the specimen shown in Figs. 12 and 16. View of the interior. P. 393.

Figs. 12, 14-19, 22, illustrate the variability of *Nuculana elenensis*. Fig. 14. is a typical *N. acapulcensis* Pilsbry & Lowe but in view of the variability of the species we have considered these all to be referable to *N. elenensis*.

All the specimens illustrated on the plate except those shown in figures 17, 18, 19, 20, 21, are in the type collection of the Department of Paleontology of the California Academy of Sciences.

PLATE II.

Fig. 1. *Nuculana* (*Saccella*) *eburnea* Sowerby. Length 12.4 mm., height 6.5 mm. Hypotype, right valve, from Station 199-D-1, dredged in 16 fathoms (29 meters) in Lat. 13° 18′ N., Long. 87° 43′ W., Meanguera Island, Gulf of Fonseca, El Salvador. P. 395.

Fig. 2. *Nuculana* (*Saccella*) *eburnea* Sowerby. Length 11.2 mm., height 6 mm., thickness (both valves) 4.4 mm. Hypotype, left valve, from the same locality as the specimen shown in Fig. 1. P. 395.

Fig. 3. *Nuculana* (*Saccella*) *eburnea* Sowerby. Length 13.3 mm., height 6.6 mm. Hypotype, left valve, from the same locality as the specimens shown in Figs. 1 and 2. View of the interior. P. 395.

Fig. 4. *Nuculana* (*Saccella*) *laeviradius* Pilsbry & Lowe. Length 7.8 mm., height 4.4 mm., thickness (both valves) 3.6 mm. Hypotype, right valve, from

Station 145-D-1, -3, dredged in 4-13 fathoms (7.5-2.4 meters) in Lat. 26° 52′ N., Long., 111° 53′ W., Santa Inez Bay, east coast of Lower California. P. 396.

This illustration shows a comparatively smooth specimen in contrast to the one with strong concentric sculpture shown in Fig. 7.

Fig. 5. *Nuculana* (*Saccella*) *gibbosa* Sowerby. Length 36.8 mm., height 18.9 mm., thickness (one valve) 8.2 mm. Hypotype, left valve, from Station 213-D-11-17, dredged in 35 fathoms (63.7 meters) in Lat. 9° 44′ 52″—9° 42′ N., Long. 84° 51′ 25″—84° 56′ W., off Ballenas Bay, Gulf of Nicoya, Costa Rica. P. 395.

Fig. 6. *Nuculana* (*Saccella*) *impar* Pilsbry & Lowe. Length, 14.6 mm., height, 7.6 mm., thickness (both valves), 6.3 mm. Hypotype, right valve, from Loc. 23802 (C.A.S.), San Luis Gonzaga Bay, east coast of Lower California. P. 396.

The character of the ribbing, closely spaced near the beaks, widely spaced on the middle of the shell, then closely spaced near the base, is characteristic of this species.

Fig. 7. *Nuculana* (*Saccella*) *laeviradius* Pilsbry & Lowe. Length 6.0 mm., height 3.3 mm. Hypotype, right valve, from Loc. 23,802 (C.A.S.), San Luis Gonzaga Bay, east coast of Lower California. P. 396.

Fig. 8. *Nuculana* (*Saccella*) *gibbosa* Sowerby. Length 37.5 mm., height 19.8 mm., thickness (single valve) 7.9 mm. Hypotype, right valve, from the same locality as the specimen shown in Fig. 5. View of the interior. P. 395.

Fig. 9. *Nuculana* (*Politoleda*) *polita* Sowerby. Length 29.4 mm., height 14.0 mm., thickness (both valves, approximately) 9.6 mm. Hypotype, left valve, from Station 197-D-1, dredged in 14 fathoms (25 meters) in Lat. 14° 16′ N., Long. 92° 03′ W., 7 miles west of Champerico, Guatemala. P. 397.

Fig. 10. *Nuculana* (*Costelloleda*) *costellata* Sowerby. Length 22 mm., height 8.0 mm., thickness (both valves) 4.4 mm. Hypotype, left valve, from Station 143-D-1, dredged in 29 fathoms (53 meters) in Lat. 26° 58′ 30″ N., Long. 111° 57′ 30″, Santa Inez Bay, east coast of California. P. 398.

Fig. 11. *Adrana exoptata* Pilsbry & Lowe. Length 20.0 mm., height 6.0 mm., thickness (both valves, approximately) 3.0 mm. Hypotype, left valve, from Station 195-D-21, dredged in 18 fathoms (33 meters) in Lat. 15° 44′ 45″ N., Long. 96° 06′ 55″ W., Santa Cruz Bay, Mexico. P. 409.

Fig. 12. *Nuculana* (*Costelloleda*) *marella* Hertlein, Hanna & Strong, sp. nov. Length 32 mm., height 11.3 mm., thickness (both valves), 5.0 mm. Holotype, right valve, apparently from the Gulf of California. P. 399.

Fig. 13. *Nuculana* (*Costelloleda*) *marella* Hertlein, Hanna & Strong, sp. nov. View of interior of left valve of holotype.

Fig. 14. *Nuculana* (*Thestyleda*) *hamata* Carpenter. Length, 12.0 mm., height, 7.2 mm. Hypotype, left valve, from Station 126-D-12, dredged in 45 fathoms (82 meters) in Lat. 28° 20′ N., Long. 115° 10′ 30″ W., east of Cedros Island, Lower California, Mexico. P. 400.

Fig. 15. *Adrana tonosiana* Pilsbry & Olsson. Length 33.1 mm., height 9.3 mm., thickness (both valves), 5.4 mm. Hypotype, left valve, from the same locality as the specimen shown in Fig. 9. P. 412.

Fig. 16. *Adrana elongata* Sowerby. Length 49.8 mm., height 12.0 mm., thickness (both valves) 5.5 mm. Hypotype, left valve, from Station 197-D-2, dredged in 14 fathoms (25 meters) in Lat. 14° 13′ N., Long. 92° 02′ W., 7 miles west of Champerico, Guatemala. P. 409.

All the specimens illustrated on this plate are in the type collection of the Department of Paleontology of the California Academy of Sciences.

MOLLUSKS FROM THE WEST COAST OF MEXICO AND CENTRAL AMERICA

MOLLUSKS FROM THE WEST COAST OF MEXICO AND CENTRAL AMERICA

26.

On the Electric Powers and Sex Ratios of Foetal *Narcine brasiliensis* (Olfers).

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Although the small electric rays of the West Indies and Florida, *Narcine brasiliensis* (Olfers), are reasonably well known and recorded as giving electric shocks of some force, little seems to be known about their uterine embryos. Bean & Weed (1911) describe and figure the young of a 17-inch specimen which contained 14 foetuses and quote the reports of trammel-net fishermen along the Florida Keys regarding the electric powers of adults.

Trammel-net fishermen operate near the New York Aquarium's field station on Palmetto Key, which is in the vicinity of Boca Grande; see Breder (1939). They report that this ray is frequently taken in their gear. The shocking powers of these fish are sufficient to cause the operators to leave them in the trammel pockets when they clear their nets. Here they are left to die, being removed later when the fishermen reach home and spread their nets for drying.

One of these groups, the Spearing family, has been very kind in bringing interesting specimens to the laboratory. On July 8, 1940, they brought in a female *Narcine* of 295 mm. over all. It had aborted two premature young in their bucket and subsequently died. Manipulation caused it to extrude six more embryos. These were still in a living state and made the usual feeble efforts of ray embryos to swim. Nothing exceptional was noted in the manipulation incident to the extrusion, but when the young were handled four of them were noted to be capable of giving electric shocks. Although in a much weakened stage and not nearly ready to be born, this shock was sufficient to cause the senior writer to drop them, although this result was perhaps as much from surprise as from the current. The fine tingling sensation was typical of an interrupted or alternating current. The young were not all in a single stage of development. The range of their condition may be estimated by the following figures of length of embryo and diameter of yolks. The two largest, dead when received, and the two smallest, showed no reaction. Whether the two smallest had not yet developed the ability or whether they were so weakened as to be unable to discharge is not clear. The over-all lengths of the embryos were: male, 65, 67; female, 65, 73, 76, 78, 78 and 80 mm. The diameters of the yolks, respectively, were: 16, 14, 5, 6, 7, 8, 9 and 7 mm. The smallest female was abnormal in that the yolk sac appeared deflated and the ventral fins were slightly asymmetrical.

One of us, Springer, handling similar material, detected no electric effects from the young, but in this case the operator is particularly insensitive to electric shocks, while on the contrary the other one of us is more than usually sensitive to such effects. In addition, moreover, Mr. L. A. Krumholz, working at the same place with the latter, also felt the discharge.

The prenatal development of this ability to give off electric shocks suggests interesting complications in the internal circuits of the mother and young and causes one to wonder what the characteristics of the exterior total current might be like. Also the question of why no discharge was felt while the young were being forced out is of note. Suppression of or impossibility of discharge before birth, insulating or dissipating qualities in the parent, suggest themselves as possibilities.

The following data were taken from material obtained from a trammel-net at Punta Gorda Beach, July 7, 1939, giving total length and width in mm.

Males		Females			
		Gravid		Non-gravid	
T. L.	W.	T. L.	W.	T. L.	W.
300	160	310	173	375	308
295	164	284	165	271	152
228	124				
272	153				

The one gravid female of 310 mm. in length contained four males 82 × 50, 79 × 42, 81 × 43, 81 × 43, and one female 84 × 45. The other of 284 mm. contained one male and three females of 78 to 80 mm. in length.

SEX RATIO OF EMBRYOS.

Length of Mother	Male	Female	% Male
284	1	3	25
295	2	6	25
310	4	1	80
432	9	5	64
	16	15	52

It is apparent that while there seems to be a tendency for the young to be predominantly of one sex in a given female, the young from so few as four females taken at widely separated times and places, when combined, closely approximate a 1-to-1 ratio. It would also appear that small mothers tend to produce more females while the large tend to a preponderance of male offspring, although of course, these specimens are too few for a basis of generalization.

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27.

A Study of the Activities of a Pair of *Galago senegalensis moholi* in Captivity, Including the Birth and Postnatal Development of Twins.

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Barnard College, Columbia University

(Plates I-VI).

CONTENTS.

	Page
Introduction	433
Description of *Galago senegalensis moholi*	434
History and Classification—Paleontology	434
Distribution	437
Conditions of Observation	437
Functioning of the Structures Characteristic of the Galago	438
The Head	438
a. Facial Expression. b. Lips. c. Nose	438
d. Eyes	440
e. Ears	440
f. Jaws, Teeth and Tongue	441
The Limbs	442
a. The Hand and its Action	442
b. The Foot and its Action	443
c. Volar and Solar Pads	443
d. The Hind Limb and its Action. aa. Climbing. bb. Moistening of Pads. cc. Jumping	443
The Reproductive Organs	445
Disposition	446
Behavior of the adults	446
Feeding	446
Grooming	447
Calls	448
Sex Behavior	448
Nesting Habits	449
Breeding Season and Period of Oestrus	449
Galago activities	449
Comparison with Breeding Habits of Other Lemuroidea	450
Discussion of Environmental Causes of Oestrus Change	451
Period of Gestation	452
Birth and Number of Young	452
Post-natal Condition of the Young	453
Nursing and Care of the Young	455
Parental Attitudes	455
Development of the Young Galago	456
Sleep	457
Acknowledgments	457
Bibliography	458

INTRODUCTION.

Galagos, small, elusive lemuroids of arboreal and nocturnal habits, are found exclusively in Africa, where they are well known and widely distributed. Though the anatomical features of the many varieties of these animals have been studied, little seems to have been reported concerning the ways in which their structures function, nor is there any sufficient record of galago habits and family life. The account is spotty and incomplete, partially at least, because their nocturnal and tree-dwelling habits render observation difficult in the field and in captivity. In a study of the galago in captivity, an effort must be made to reproduce in some measure certain elements of its native environment, such as perching structures, space for jumping and dark places for retirement during daylight hours. The nocturnal habits of the group necessitate the observer's continuous occupancy of the animals' night quarters.

For more than three years, beginning September, 1937, I have made a close study of a pair of *Galago senegalensis moholi* A. Smith, a subspecies

of galago found in abundance throughout the savanna country of central and southern Africa. The opportunity to study these unique and interesting forms was enlarged by the fortunate birth of twins in captivity, making a family of four. Thus it has been possible to add, to the story of the behavior and disposition of the adults, a record of the birth and development of a male and female in captivity. While in the following discussion I have emphasized observations of their habits and family life, I have also described the functioning of those structures which are characteristic of the galago.

Description of *Galago senegalensis moholi.*

The *Galago s. moholi* is a small, round-headed animal with a shortened face; large, almost naked, membraneous ears with transverse ridges; round, wide-open eyes with vertical pupils, and a short rhinarium situated high on the face (Pl. I, Fig. 1).

The body length including the head of the adult male is 6½ inches and the long, non-prehensile tail, which is used for balancing, 8½ inches. The front limbs are shorter than the long hind limbs. The foot, which is highly specialized for jumping, has elongated calcaneum and navicular bones, providing adequate leverage for spectacular jumps.

The opposable huge hallux and less well developed pollex are primate characteristics possessed by the galago, as are the small, and in this species flattened, nails found on all the digits with the exception of the index toe. Here a claw, characteristic of the Lemuroidea, is found.

The dental formula of the *Galago s. moholi,* like that of the true lemurs, is

$$\frac{2\ i}{2} \quad \frac{1\ c}{1} \quad \frac{3\ p}{3} \quad \frac{3\ m}{3} \quad \text{- - 36 total}$$

The two pairs of procumbent lower incisors are flanked by modified canines, making the typical lemuroidean "tooth-comb."

The neck of the galago is short. The pelage is soft, heavy and almost chinchilla-like. The color of this subspecies is a mottled slate gray and silver with a light brown wash on the dorsal surface of the posterior half of the body. The ventral surface is largely white with slate gray on the deeper portions of the fur, seen only when the fur is separated.

On the inner surface of both arms and legs and across the chest, the pelage is clear yellow. There are white markings on the nose, around the neck and lower jaw. Through the usual gray of the dorsal pelage, longer black hairs protrude sparsely (Pl. IV, Fig. 9). There are black markings around the eye and along either side of the nose from the eye toward the upper lip (Pl. I, Fig. 1). The pelage is shorter near the hands and feet, and more silvery in color.

There are no well defined sex differentiations. The adult male is slightly larger than the female and the yellow of the pelage perhaps more marked. The length of the tails in this group varies between 8½ and 10 inches. (The tail of the adult female under discussion is unnaturally short because of an injury to the tip sustained at capture (Pl. V, Fig. 12).

History and Classification—Paleontology.

In 1796 Étienne Geoffroy-St. Hilaire first described one of the "quadrumana" which the natives called "Galago," found in western Africa in the region of Senegal. A skull of this form was brought to him at the Museum in Paris by Michael Adanson who had spent some years in exploration of

the Senegal, and a skin was later provided by the Duc de Nivernais. The addition of pictures and descriptions furnished by Adanson led Geoffroy to the conclusion that this was a new type of animal which resembled in many respects the makis (lemurs), the lorises, and tarsier. It differed from each of these, however, to such an extent that he felt justified in calling this a new species intermediate, perhaps, between the *Loris* and the *Tarsius*. He determined to adopt for it the native name "Galago" to which he attached "du senegal," perhaps to distinguish it from two other forms (one larger and one smaller) which Adanson had reported to be present in that region. He described[1] it as possessing hind legs longer than the body, built for jumping; the front legs short; the tail longer than the body; ears large and membranous with transverse ridges.

Like the lemurs there were nails on hands and feet with the exception of the second toe which had a claw. The hind foot was very long due to the elongation of the calcaneum and scaphoid (navicular). The fur was grayish-tan on the dorsal surface and white with yellow on the under surface. It was also shorter on the hands and head while the under side of the hands and feet and the ears and nose were naked. The animal was described as arboreal and insectivorous. Geoffroy incorrectly stated that there were but one pair of upper incisors.

In 1836 Sir Andrew Smith described a galago of similar size which he found near the Limpopo River, Bechuanaland, South Africa, which closely resembled Geoffroy's *senegalensis*, but differed from it in two features.

1. On the ventral surface of the body the fur was white on the tips of the hair only; near the body it was slate gray.
2. There were two pair of incisors on the upper jaw instead of one pair as described for *senegalensis*.

On the basis of these differences he felt compelled to consider this a new species and called it *Galago moholi*, which is the Bechuana name for the animal in that locality.

"Had the upper jaw on this species not been furnished with four cutting teeth I should have been disposed to have considered it as identical with *Galago senegalensis* of Geoffroy." (Page 42).

For some years thereafter, the few species of galagos known were classified in accordance with the number of upper incisor teeth described for each. When, however, in 1851 Isadore Geoffroy-St. Hilaire reported that all galagos normally possessed two pair of upper incisors, the main reason for separating *Galago senegalensis* from *Galago moholi* disappeared.

"Les Galagoides de M. Smith sont les espèces qui n'auraient que deux incisives supérieures, et par conséquent trente-quatre dents en tout. Tels seraient, suivant lui les *Galago senégalensis* et *demidoffii*. Cette charactéristique est erronée; ces espèces ont normalement quatre incisives supérieures comme les autres; seulement deux sont caduques, comme il arrive si souvent chex les Lémurides." (Page 80.)

The *Galago moholi* is now recognized as a sub-species of *Galago senegalensis*. According to W. L. Sclater, 1900, (Page 23),

"This little Lemur is closely allied to the West African form with which it has frequently been confounded, but an examination of the two species (*Galago senegalensis* in Paris and *Galago moholi* in London) shows that they are really distinct."

According to E. Schwarz (1931), the Galaginae fall naturally into two genera: (1) *Euoticus* with pointed nails; (2) *Galago* with flat nails. *Euoticus* is represented by a single species (*elegantulus*). Members of the genus

[1] The dimensions were given as follows:

Body length	6 inches 10 lines
Tail length	8 inches 4 lines
Head length	1 inch es 8 lines
Anterior limbs	3 inches 4 lines
Posterior limbs including feet	6 inches 11 lines

Galago, however, are numerous and Schwarz divides them provisionally into four species:

1. *Galago crassicaudatus*
2. *Galago alleni*
3. *Galago demidoffii*
4. *Galago senegalensis*[2]

The Galaginae, because of their long tails and ability to jump, are called "African long tailed Lemurs;" other anatomical details, however, relate them more closely to the short tailed, climbing, loris-like forms of Asia and Africa. The current classification of the Lemuroidea provides for two main divisions, the Lemuriformes and the Lorisiformes (W. K. Gregory, 1916), subdivided as follows:

Suborder Lemuroidea[3]

Division A. Lemuriformes—all inhabitants of Madagascar
- Family 1. Lemuridae
- Family 2. Indrisidae
- Family 3. Chiromydae

Division B. Lorisiformes—Inhabitants of Asia and Africa
- Family 1. Lorisidae[4]
  - Subfamily 1. Lorisinae
    - *Arctocebus*—West Africa
    - *Perodicticus*—West Africa
    - *Nycticebus*—N. India to Philippine Is.
    - *Loris*—S. India, Ceylon
  - Subfamily 2. Galaginae
    - *Euoticus*—Tropical and subtropical Africa
    - *Galago*—Tropical and subtropical Africa

Palaeontologically the time and place of origin of the Lorisiformes, unlike those of the Lemuriformes and the Tarsioids, are obscure because of total lack of fossil evidence. Dr. George Pinkley of the American Museum of

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[2] R. W. Hayman (1937) further emphasized the difference in nail structure among the Galaginae. He demonstrated that *crassicaudatus* has concave nail ends while *demidoffii* Fischer, *alleni* Waterhouse and *senegalensis* Geoffroy all have nails which are bluntly rounded at the ends with the exception of *Galago senegalensis inustus* Schwarz. Because this form possesses pointed and keeled nails he is convinced that *inustus* Schwarz should have the status of a new species.

[3] The relation of the Lemuroidea to other primates is not the function of this article; however, a brief outline of recent trends in Primate classification may be pertinent.

Classification of Pocock—Zuckerman (1918) (1933)	Allen-Coolidge modification of Pocock, Schwarz. Zuckerman, as outlined by R. M. and A. W. Yerkes, 1935
Order Primates	Order Primates
Series 1. Strepsirhini	Division 1. Prosimiae
Suborder Lemuroidea	Suborder 1. Lemuroidea
Div. A. Lemuriformes	Suborder 2. Tarsioidea
Div. B. Lorisiformes	Division 2. Anthropoidea
Series 2. Haplorhini	
Suborder Tarsioidea	
Suborder Pithecoidea	

Dr. George G. Simpson is now (1940) revising his classification, the main outline of which, exclusive of fossil forms, is as follows:

- Order Primates
  - Suborder Prosimii
    - Infraorder Lemuriformes
      - Superfamily Tupaioidea (Tree or squirrel shrews)
      - Superfamily Lemuroidea (Malagasy lemurs and lemuroids)
    - Infraorder Lorisiformes (Lorises, pottos, galagos—no fossil forms)
    - Infraorder Tarsiiformes (Tarsius and fossil tarsioids)
  - Suborder Anthropoidea

While the relation of the Lemuriformes and the Lorisiformes is not changed, the term Lemuroidea is relegated to that of a superfamily instead of the more inclusive one of suborder, and the term Lemuriformes includes the primitive Tupaiodea as well. The Tarsioids, as in the case of the Allen-Coolidge modification, are put back once more with the Prosimii.

[4] Some authors rank the two subfamilies as families, Lorisidae and Galagidae, respectively. In that case no subfamilies are indicated.

Natural History, in the following memorandum to the author (1940) elaborates this statement as follows:

"The occurrence of fossil specimens of the lower primates indicates that in the geologic past the geographic distribution of these forms was singularly different from that of today. Specimens representing the Lemuriformes and Tarsioids (but not the Lorisiformes—lorises, pottos, and galagos), are found in fossiliferous deposits in both Europe and western North America. They are first known from middle Paleocene formations in America, seem to have spread over holarctic regions and appear in late Paleocene deposits of Europe. They range through the Eocene, disappear in the late Eocene in Europe but not until the early Oligocene in America. Lower primates are then quite unknown in the fossil record until the appearance of Lemuroids in the late Pleistocene of Madagascar, where they are now confined. And *Tarsius*, living today in the Malay archipelago, is the only surviving representative of the Tarsioids. This leaves a hiatus in the fossil record of nearly two-thirds of Cenozoic time—about forty million years.

"It is furthermore remarkable that the paleontological history of the Lorisiformes is entirely unknown although living forms are widely distributed through tropical Africa and the Indo-Malayan region. It is true that the French Eocene forms *Pronycticebus* and *Pseudoloris* were formerly believed to represent fossil Lorisoids, but more careful examinations indicate that they represent a Lemuroid and a Tarsioid, respectively. There is good reason, from comparative anatomical studies, to believe that the ancestry of Lorisiformes is approximately as ancient as is that of Lemuriformes. It therefore seems probable that during the time when the fossil record of Lemuriformes and Tarsioids was accumulating in limited areas in Europe and western North America, early Lorisoids were living in some other part of the world—possibly Asia or Africa."*

Distribution.

Euoticus, Galago alleni and *G. demidoffii* are forest dwellers, while the six varieties of *crassicaudatus* and ten varieties of *senegalensis* are found only in the savanna country, a type of environment defined by botanists as "grassland with scattered shrubs and medium-sized trees." (J. Chapin, 1933, page 103). According to Shortridge (1934), typical *senegalensis* and other races of the species range through Africa to as far north as Senegal, Nigeria, French Equatorial Africa, the Southern Soudan, Gallaland, and Somaliland and as far south as Inhambane in Portuguese East Africa, but apparently not south of the Southern Transvaal. According to Sclater (1900), Schwarz (1931) and Shortridge (1934), the subspecies *moholi* is widely distributed over eastern, southeastern, southern and southwestern Africa, in the north at least as far as the Tabora district in Tanganyika Territory, possibly extending further northwest.

Conditions of Observation.

For the first two winters, I shared the same room with the adult pair of galagos. During the day, the animals were confined in a cage 6×4×4 feet. On a shelf in the cage was a small sleeping box which provided the needed darkness. At night for periods of two to five hours, they were liberated and given the freedom of the room for exercise. A shaded light made observation possible without distress to the animals. By placing food on their feeding shelf, they were finally coaxed back into the cage. While sharing a room with a pair of galagos had obvious disadvantages to the observer, nevertheless, it offered the surest method of obtaining detailed data throughout their active period. During the exercise period, all damageable articles were covered with sheets. At frequent intervals the walls of the room were washed down.

* According to Dr. W. K. Gregory the removal of *Pronycticebus* from the Lorisidae to the Adapidae by Dr. G. G. Simpson (1940) deprives the Lorisoids of any known early Tertiary representative.

From June to September, the galagos were removed to the country, where they enjoyed the complete freedom of a screened-in porch 10×14 feet, adjoining my room. As usual, they slept in a sleeping box on a shelf. Several times each night their activities were checked.

The birth of the young galagos occurred in the second spring, April, 1939, in the apartment room, under the most favorable conditions for continuous observation.

The third winter, when the young animals were half-grown, the inconvenience of caring for so large a family made advisable their transfer to a 10×7 feet partitioned section of a heated greenhouse on the roof of Barnard College, Columbia University. While conditions now prevent a constant watch, some record of activity is made at varying intervals, at least three times each night, twice by myself and once by the night watchman.

In the daytime the animals sleep fairly continuously. A darkened and elevated recess in the cage, greenhouse or porch protects them from the sunlight. Their quarters are kept scrupulously clean by frequent scrubbing.

In both the greenhouse and the screened-in porch, small growing trees planted in tubs have been provided, as well as horizontal and vertical round, wooden, exercise bars. One side of the porch is screened by half-inch meshing, large enough to admit moths, the galagos' favorite fare. The moths and other insects are attracted by a light with a reflector situated in the enclosure.

Full-sized doors leading into both the greenhouse enclosure and porch make it convenient for visitors to enter and watch at close range the behavior of the galago family.

The *Galago s. moholi* seems to be hardy. It can tolerate a wide range of temperatures from summer heat of more than 90 degrees in their sleeping box to as low as 40 degrees on a cold winter night.

Functioning of the Structures Characteristic of the Galago.

It is my purpose at this point to supplement the outline of the known features of the adult *Galago s. moholi* by further details based on my own observations of the functioning of the outstanding structures which differentiate this form. From time to time when possible I have attempted to compare these structures with those reported of closely related lemuroids, as well as with *Tarsius,* which, while not so closely related, displays many interesting similarities and differences.

The Head.

a. Facial Expression. b. Lips. c. Nose.

The galagos, like the Lemurs, are extraordinarily expressionless—"notoriously blank," as S. Zuckerman has expressed it. They cannot (A. Smith to the contrary) make grimaces or even wrinkle the brow. They can merely stare or droop their lids, move the ears and open the mouth wide enough to expose the teeth.

This lack of facial expression is due in large measure to the immobility of the upper and lower lips. There are two reasons for this condition: 1. the middle of the upper lip is bound by the frenulum to the underlying premaxillary area; 2. the lack of development of the labial and nasal muscles of the facial field. Ernest Huber 1931, (page 23) who has made an exhaustive study of facial muscles of mammals and primates, states that:

"The facial muscles of the Lemur play no role as musculature of facial expression. Indeed we can hardly speak of facial expression in the Lemur."

In common with all other Lemuroidea and many mammals, the galago has a moist, glandular rhinarium with crescent-shaped nostrils, which E. Geoffroy-St. Hilaire (1812) and R. I. Pocock (1918) call strepsirhine. This structure extends into the labial area and becomes the philtrum, or median, attached part of the upper lip. Maxillary portions of the upper lip which are covered with fur may terminate on either side of the naked philtrum as in the case of the lemurs, or, as in the *Galago s. moholi* (Pocock, 1918, and J. D. Boyle, 1932) may meet in front of (over) the labial portion of the rhinarium, a deep groove remaining to show the line of union. In this way the upper lip is completely bounded by fur (Pl. I, Fig. 1).

When the *Galago s. moholi* is angry and prepared for defense or offense, it opens the mouth so wide that the labial area is stretched and the canines and premolars exposed. There is no ability to draw up the lip in a snarl or to make grimaces of any sort. The enlarged photograph (Pl. I, Fig. 1) of the face of one of the galagos shows the preliminary stage of rage. The mouth is partially opened though not wide enough to show the teeth. The eyes are focused on the cause of irritation located just above its head.

The sense of smell of the galago as of other Lorisiformes is well developed and still serves a more important function than in the higher primates.

Le Gros Clark (page 177) states that:

"In general there is a close correlation between the degree of complexity of the turbinate system and the acuity of smell." . . . "In Lorisiformes the first ethmo-turbinal is very large and actually covers over the maxillo-turbinal while in Lemuriformes it is much smaller."

The presence of a relatively large olfactory lobe in the brain is additional evidence that the galago and the lemurs, in common with the lower mammals, retain their dependence on the sense of smell.

The galago places great dependence upon its sense of smell. Curiosity is satisfied through this means. Any strange person, or object, is first thoroughly smelled, or food is approached nose first unless it is food-on-the-wing, when it is seized first and smelled afterwards. The facial tactile vibrissae, or "whiskers," around the nose are said to be closely associated with the sense of smell. Though they are not as well developed as in the genus *Lemur*, they are still evident in some degree. The mystacial, mental and genal, are present though more delicate and less obvious (Pl. I, Fig. 1) than in *Lemur*. According to Ernst Huber (pages 22-23), among the Lemurs:

"The mystacial and mental vibrissae jointly with the rhinarium, a highly sensitive patch of mucous membrane at the tip of the snout, subserve the tactile sense of the latter, which is closely associated with the sense of smell. . . . This sense, which plays an eminent role in the life of the primitive, terrestrial mammals, is of subordinate importance in the primates and has already become deteriorated in the Lemuroidea. Undoubtedly in connection with their adaptation to arboreal life, the sense of touch, with the aid of the facial tactile vibrissae, is, however, of the greatest usefulness to these primitive primates in their life amidst the branches of trees. Indeed, the sense of touch together with the highly developed sight and keen hearing are the guiding senses of the lemur."

In my judgment the sense of smell should be added as an important guiding sense.

The mouth and nose of the *Tarsius* are strikingly different from those of the galago or other lemuroids. There are no crescent-shaped nostrils with moist rhinarium extending into the upper lip. Like higher primates, the nostrils are oval and there is only a remnant of the moist area about these apertures, a condition which Pocock (1918) considers of such fundamental importance that in the classification of the primates he uses this feature as a basis for primary subdivision. He calls the lemuroids "Strepsirhini" and all other primates including *Tarsius*, Haplorhini.

d. Eyes.

The large, round eye bulges forward, giving a conspicuously rounded appearance to the surface. In the daylight the entire surface of the eye is colored a homogeneous light brown. Since the whole visible portion of the eye is covered by the rounded, transparent cornea, no portion of the sclera can be seen. The pupil, as A. D. Bartlett (1863) observed long ago in the case of *Galago crassicaudatus montieri*, is vertical (Pl. I, Fig. 1), a condition common to Lemuroidea and to many nocturnal mammals. *Tarsius*, however, differs from the galago in that the pupil is horizontal. A recent photograph which appeared in Collier's Magazine (August, 1939) of Professor John Fulton's two living specimens at Yale University, shows the pupil in the light as a horizontal slit, although in their other respects the eye is strikingly similar.

Under the hand lens, the vertical pupil of the galago eye appears to be slightly rounded at each end and somewhat wider in the center. Fine dark lines radiate from the rim of the slit into the iris. The spacing of the lines seems to vary with the intensity of the light. When the light is bright and the slit narrow the lines seem crowded together. In a dimmer light, the slit is larger and the radiating lines farther apart. A slight scalloping of the edge of the slit between the lines is apparent. At night in a dim light the iris opens to a prodigious extent, leaving only a small portion of the brown visible as a rim. By reflected light the pupil is brilliant orange (like the lemur). The eyelids, which are kept wide open, have lashes on the rims visible on the upper lid of the right eye in the enlargment (Pl. I, Fig. 1). It is difficult to see the lid except when the animals are sleeping. We succeeded in getting a photograph of a form with extended lid after it had been temporarily blinded by a flash-light bulb which it was examining when the light was discharged. The photograph clearly shows the upper lid covering the major portion of the bulging eye (Pl. II, Fig. 3).

The eye is so large that the extrinsic muscles are unable to move it. In compensation the head moves flexibly as a whole in quick motions from side to side and sometimes in an elipse. The head may be bent to the side at such an angle that one eye is placed almost vertically above the other. It may also turn practically 180 degrees so that the nose is directly over the spine and, as Cooke (1939) has noted in the case of the *Tarsius*, the animal frequently moves its head in this manner to look upward. The galago does this when it is clinging to some vertical or inclined branch or when clinging upside down to a horizontal branch. The ability to turn the head in a direction opposite to that which the body "faces," a convenient adaptation for any perching animal, relieves the necessity of lessening the hold on the perch.

e. Ears.

The membraneous ears are large and almost naked on the inner and outer surfaces except at the rim where there is a sparse covering of fur (Pl. I, Fig. 1). The inner surface, as E. Geoffroy-St. Hilaire first and A. Smith later noted, is marked by four transverse ridges which seem to terminate in an outer vertical ridge (Pl. I, Fig. 1). An outstanding galago pecularity is the ability not only to move the ear as a whole forward, laterally or upward, but also to fold the pinna along the ridges somewhat like an accordion, throwing its outer tip back over the upper transverse ridge. In addition to the accordion-like folding, the whole pinna may be further pressed back against the head so that all evidence of large projecting ears disappears.

The ears of the galago are perhaps its most expressive feature. They move singly or in unision in the direction of the least unexpected sound. When looking over a new object or person the ears seem as alert as the nose and the eyes. In sleep there is a tendency to fold the pinnae along the

ridges (Pl. II, Fig. 2, lower center) and in anger there is also some tendency to corrugate them (Pl. II, Fig 2, right). The final flattening of the folded pinnae against the head occurs when the animal enters an enclosed space. When seeking food which I have placed in the cupped palm of my hand, the galago thrusts forward both head and hand, invariably flattening the ears against the sides of the head. This is an admirable device for the protection of large and delicate ears from the dense foliage and perhaps also from the perils of battle.

Tarsius ears, though much smaller relatively, seem to be of a similar type, according to Ernest Huber (page 27), and the musculature which moves them is highly developed.

f. Jaws, Teeth and Tongue.

The round head and short face are characteristic of the several varieties of *Galago senegalensis* and *demidoffii*. The upper jaws and the snout with the crescent-shaped nostrils do not project forward to the extent that they do in *Galago crassicaudatus* or in the Malagasy lemurs. The lower jaws, which are also short, bear the usual two pairs of procumbent incisors flanked by the elongate modified canines that project forward almost horizontally and have been known as the "tooth-comb" of the lemurs. The teeth of this incisor-canine complex of the lower jaw converge at their tips so closely that, as M. Russell Stein (1936) points out in the case of the true lemur, the term "comb" is probably inaccurate. "Scraper" is perhaps a more accurate term. The* first premolar of the lower jaw has become modified into a somewhat caniniform structure though less so than in the true lemurs. By working against the canine of the upper jaw, this tooth acts as a shearing or a nipping apparatus. The remaining molars and premolars are more advanced than those of the typical insectivorous lemurs as Le Gros Clarke (1934) has recorded, since the† third premolar of the upper jaw is more molarized and the first two molars are quadri-tubercular, having one more cusp than those of the typical lemurs. The two pair of upper incisors, separated by a space in the center, are so small that it has been suggested they are functionless. Because of the strong roots possessed by these teeth in the case of the true lemurs, M. Russell Stein questions this idea. Can these upper teeth function with the lower horizontally placed incisor-canines or can they be used in any other way? I can confirm the statement made by Stein that the upper incisors are functional. The galagos in my possession will frequently bite when handled, and several times the bite has been sufficiently severe to leave a clear imprint of the tooth marks. In each instance the imprints of the upper canines and the two pair of incisors which lie between have been evident, as well as the imprint of the pair of lower caniniform premolars and the scraper itself.

The question of the use of the incisor-canine complex or scraper is an interesting one. In an article published in 1939 on "The Feeding and Grooming Habits of the Galago," I attempted to show that the scraper was used as a toilet or grooming structure. Since then I have experimented further to determine whether, as suggested by Stein, this device is ever used for scraping fruits and biting off leaves. On placing a pear upon the feeding shelf, I found that the scraper was never used. The galago attacked the pear with the canines of the upper jaw and after making a hole in the skin it then inserted its long, thin tongue into the aperture and licked out what it wanted from the interior. Again, when a tree was placed on the porch some of the smaller branches were bitten off. In each case the canines and the first premolars of the lower jaw were used, never the incisors. The general conclusion is that the scraper of the lower jaw, in the case of the galago at least, is essentially a grooming implement though it has not yet been proved that it may not act upon occasion as a food-scraping device.

* Homologous with P_2 of the primitive mammalian dentition.

† P_4 superior of the primitive mammal.

The long, thin tongue, like that of the true lemurs, is used for licking and lapping. Although of somewhat limited movement, its action is straight forward over the incisor-canine complex of the lower jaw which acts as a trough. The tongue is long enough to reach the moist rhinarium over which it can curve.

It is interesting to note that *Tarsius* also uses its tongue as a licking and lapping structure.

The Limbs.

a. The Hand and its Action.

It is well known that the fourth digit of the hand among the Lemuroidea is the longest of the five. In this characteristic, they differ from all other primates, including *Tarsius*, and from Mammalia generally where the third digit is the longest. The hand digits of *Galago s. moholi* as a whole are relatively long. The thumb is short and separated from the index finger by a considerable interval; the index finger is also short and separated from the third digit by a less marked interval (Pl. III, Fig. 6). The third and fourth fingers grow progressively longer with the fifth somewhat shorter. The last three digits are more closely placed (Pl. III, Fig. 4).

In 1838 W. Ogilby demonstrated at a meeting of the Zoological Society of London the structural peculiarities of the hand of a living specimen of galago, then known as *Otolicnus garnetti*. This peculiarity consisted in the partially opposable character of the index finger of the hand. It was shown that the thumb and the index finger could be used as a unit to grasp one side of a branch and that the remaining three fingers were used on the other side, much as the koalas would do. Mr. Ogilby remarked, "The anterior index finger in all the 'inferior' Lemuroidea is weak and powerless and it has the same tendency to divide with the thumb instead of with the other fingers in the rest of the galagos as well as in the Nycticebi, the Microcebi, the Cheirogalei, and Tarsii whilst in the Potto it is reduced almost to a tubercle." In watching the action of the anterior digits of the galago, I find that my observations do not agree with Mr. Ogilby's in all respects. The index finger lies almost midway between a large space which separates the thumb from the third finger (Pl. III, Fig. 6) and, in grasping, it is just as likely to be found with the third, fourth and fifth digits as with the thumb. Its disposition depends somewhat on the size of the object grasped. If it is small enough to fit in the space between digits two and three, digit two is then likely to be found on the side of the thumb (Pl. I, Fig. 1); if, however, the object or branch is large, the index finger then lies almost between the two. In any event the index finger is so small that its effectiveness as an opposable structure is very limited.

An interesting feature of the digits of the hand is the size of the individual phalanges of all but the thumb. In each instance the proximal phalanx is long and the second one is slightly less so while the third or distal phalanx is minute and very little larger than the nail. The relative length of the phalanges is an admirable adaption for grasping limbs and small branches of trees. Two peculiarities, however, are evident because perhaps of the elongation of the proximal elements. 1. When the galago places its hand upon a flat surface, the palm of the hand with its pads rests flat upon the surface; the digits, however, are not extended straight forward but are flexed, the pads on the distal ends of the digits alone resting upon the surface. There seems to be a flexure at the knuckles which permits the raising of the proximal phalanges away from the ground. Furthermore, the joints between the first two phalanges instead of pointing directly upward are bent to the side, even the index finger may be involved (Pl. III, Fig. 4). A recent motion picture of Dr. John Fulton's live *Tarsius* shows the same flexed condition of the digits when the hand rests upon a flat surface. 2. A

second peculiarity is to be noticed when the galago grasps a piece of food. Among the other primates the digits flex over the object at the knuckles and the palm of the hand is involved. In this instance, however, the proximal phalanx of each digit (the longest) remains straight on a plane with the back of the hand, and the grasping is done by flexing the two distal phalanges over the proximal. The thumb acts in opposition and the palm is not covered by the digits (Pl. III, Fig. 5).

b. The Foot and its Action.

The enormous hallux of the foot is widely separated from the other four toes which act as a unit (Pl. III, Figs. 6, 7; Pl. IV, Fig. 8). The fourth digit, in this instance like that of *Tarsius*, is again the longest of the five, while the second toe is short and, as in the case of all other lemuroids, bears a flexed claw (Pl. IV, Fig. 10). All the other digits of both hands and feet have nails which are flat with relatively straight edges (Pl. III, Fig. 4) (A. Smith, 1836). The great distinction of the foot of the galago as compared with other lemuroids is the extraordinary elongation of the navicular (scaphoid) and the calcaneum first noted by E. Geoffroy-St. Hilaire. The digits and distal portion of the metatarsals are the only elements which rest upon the ground. The proximal portion of the metatarsals are well as the tarsals are always off the ground; in fact, as Pocock (1918) has admirably shown, the ventral aspects of this area of the foot are covered with fur and are usually raised some distance from the ground (Pl. III, Fig. 7; Pl. IV, Figs. 8, 9). The total length of the foot is 2 to 2¼ inches, about half the length of the hind leg. It is this unusual lengthening of the tarsal segment which makes possible the extraordinary leaps characteristic of this form.

c. Volar and Solar Pads.

The well developed pads on the palm and the sole of the galago are quite primitively disposed in a characteristic manner (Pl. III, Figs. 6, 7). There are two proximal pads, the thena and the hypo-thena, and four distal interdigital pads. In both hand and foot the thena pads tend to fuse somewhat with the first interdigital and the hypo-thena with the fourth interdigital. The interdigital pads of the foot are not all of equal size, the third being much smaller than the others.

Pads also are to be found on the toes and fingers (Pl. III, Figs. 4, 6, 7). Along each digit between the palm or sole, and its tip, a long, thin pad is found which enlarges at the tip. Although this enlargement or pad is not equal in size to that found on the tip of the *Tarsius* digits, it is, however, an effective surface. The big toe has a broad distal and proximal pad. The first interdigital which follows is a round, conspicuous pad, protruding beyond the confines of the digit and the sole (Pl. III, Fig. 7). Oblique papillary ridges are to be seen on the pads. Dr. Charlotte Wolff (1938) has found "unique scale-like roughness" in two species of galago (*moholi* and *crassicaudatus*) as well as in *Loris* and in the genus *Lemur*. She describes them as more expressed on the sole than on the palm and are found in the center of the palm and sole and on the lower phalanges but not on pads. She also finds that all the terminal phalanges have tactile corpuscles.

d. *The Hind Limb and Its Action. aa. Climbing.*
bb. Moistening of Pads. cc. Jumping.

Not only is the hind limb very long, but its strength is also enormous. The animal can hold on by its hind feet alone (Pl. IV, Fig. 9); it can lower itself down into a jar, or suspend itself freely, head downward. By the power of the muscles of its hind legs, combined with the strength of the muscles of the foot, it can lift itself once more to its original position without the aid of the anterior limbs. One of the tamer individuals born in captivity will

grasp a finger of my hand by the huge opposable big toes and the other digits of its hind feet and will let itself down into a paper bag suspended from my hand. The strength of the grasp of the large toe and the other digits upon my finger seems out of proportion to the size of the animal. There seems also to be a particular pressure exerted by the hallux and the inner surface of the sole of the foot. This is the area where the interdigital suction pads are especially well developed. The added pressure exerted at this point flattens out the adhesive pads and makes them more effective as a clinging device. The use of the pads as an aid to clinging is shown in the illustration (Pl. III, Fig. 6). This photograph was taken from the inner side of a glass door on the outer side of which the galago was clinging. The pads of the hind feet press against the flat surface of the glass, obliterating the spaces between the pads and show the way in which the large pads of the big toe and the first interdigital adhere firmly to the glass surface. This explains the animal's ability to climb up and down any perpendicular surface which offers an edge, such that the thumb and great toe can get a purchase. The galago always descends head first.

Grasping and climbing are facilitated not only by the elongation of the fourth digit over that of the third and by the strength and opposability of the very large, widely abducted hallux, but also by the moistening of the pads of both hands and feet. The latter action is one characteristic of the galago which is accomplished in a definite way at frequent intervals throughout the active period, whether climbing or sitting still. By placing the palm of one hand under the urethral aperture, the animal collects a drop of urine. It then rubs the moistened palm of the hand on the sole of the foot of the same side, repeating the action with the other hand and foot. This automatically moistens the naked surfaces of the pads and renders them more effective surfaces of adhesion. No one seems to have recorded this action except E. G. Boulenger, who, in his popular book, "Apes and Monkeys," states that the galago has "a strange habit of moistening the palms of the hands and the soles of the feet at frequent intervals when climbing" (p. 206), although he gives no clue as to the way in which this is accomplished, nor does Mr. Boulenger record this as a common practice even when the galago is sitting quietly.

The galago, essentially a hopping and jumping animal, normally perches in high places (Pl. IV, Fig. 8). Although it uses all four feet for climbing and usually for perching, it does not normally run or walk on all fours. The structure of the posterior limbs is responsible for the characteristic hopping and leaping motions. When jumping on a horizontal plane this form can span as much as six feet. Vertically it can spring upward as much as five feet, landing on a perch with unerring precision. When jumping downward diagonally from a higher to a lower perch much greater distances are covered.

As an example, one of the adults sprang from the balcony rail of a studio room to the top of an open door in the room below, a distance of twenty feet. Although the thickness of the door was only two inches, the landing was made with precision. When, and rarely, the adult galago makes an imperfect landing, it seems to be due to an insecurity of grasp rather than inaccuracy of gauging distance. The speed and extent of the jump is particularly great in this variety and exceeds that of the larger species (*crassicaudatus*).

The preliminary stages of jumping are expressed by a crouching of the body. The hind feet are placed with heels together off the ground and toes out. The spring is made with great speed and the feet are kept in the same relative position as attained when taking off, though somewhat farther apart. From a front view of the approaching animal the soles of the feet can be seen slightly up-raised. The heels are no longer touching, but may

remain relatively close together. This explains the ability of the galago to jump even though his legs are bound together above the heel. Donald Carter, in his field notes of his trip in South Africa (1938), recorded the following:

"Balovale, September 4.—A native brought us four (two males and two females) galagos alive in a gourd. Upon removing the wad of grass which served as a plug for the hole, one of the animals jumped out landing on the table. From there it jumped a good six feet to one of the posts supporting the tent and without a moment's hesitation he took another jump to the trunk of a small tree under which the tent was pitched. This jump must have been eight feet. Up this tree he scrambled and hid among the boughs. I sent a boy up the tree and with some difficulty the animal was dislodged and jumped to the ground where he was pounced upon by about five small boys who were waiting underneath. It was not until he was retrieved that I noticed that the animal had his two hind legs securely tied together at the ankles by a piece of grass. Hampered as he was he easily and gracefully made these two jumps landing both times where he had planned."

Before taking off to a new position the eye of the galago always gauges the distance to be covered quickly and carefully. The jump to a new perch may involve a diagonal or backward leap. The animal, however, always manages to face the new perch on landing, though it may mean a 180 degree turn in mid-air.

Occasionally the galago will stand up straight, balanced on its toes with the hind limbs not flexed. In such a position, it immediately becomes quite tall (11 inches) and of a short-waisted appearance because of the relative length of the hind legs and feet (Pl. IV, Fig. 10). The tail, from eight to ten inches long and somewhat bushy at the end, serves as a balancing structure when jumping or when standing upright. In the latter action the tail moves up and down to help maintain balance. It may also serve to protect the eyes from the light while sleeping, though it is more frequently curled over the breast at such times. While the tip of the tail continues to be slightly curled when the animal first awakens, it straightens out as soon as the galago becomes active.

The Reproductive Organs.

R. I. Pocock in his admirable article, "On the external Characters of the Lemurs and Tarsius," (1918) has described in detail the structure of both male and female reproductive organs of *Galago senegalensis, crassicaudatus* and *montieri* as well as other forms of the Lemuroidea. The presence of baculum and spines on the penis seems to be a condition common to all male Lemuroidea but invisible of course in the living state.

The male in conformity with the lemuroid type (except the genus *Lemur*) has an external scrotum covered with fur. The penis is relatively short with a long, inverted tip. Recently, just before the period of heat of the female, (December, 1939) I saw the everted tip of the penis. Its shape differed from those described by Pocock for *crassicaudatus, senegalensis* and *demidoffii.* The everted portion was a relatively narrow cylinder, over an inch in length, which expanded suddenly into a wide bulb at the tip. As I watched, the bulb suddenly contracted with startling speed to almost the dimensions of the rest of the penis. As I was fully six feet away from the cage when I saw this structure, it was not possible to see whether the bulb after contracting formed a structure comparable to the "frill" which Pocock described as present in the case of the tip of the penis of *Galago crassicaudatus.*

The female *Galago s. moholi,* as Pocock has shown in the case of galagos of other species, possesses a long, pendulous clitoris, at the terminus of which is the urethral aperture. This peculiarity makes it difficult to determine the sex of the individual as the structure resembles superficially a penis in shape and length. The inverted tip of the penis and the presence of the permanent scrotum, however, differentiate the male.

Disposition.

The galago is a very quick and nervous animal, which responds to the slightest unexpected noise or movement. It will crouch in terror and then spring away from the direction of danger with lightning speed. Like most lemurs, though easily tamed, it is somewhat truculent and uncertain in its relations to humans. It resents handling. Balancing on its haunches, it will hurl itself forward, striking out first with both hands like a diminutive prize fighter, and then grabbing hold of the object. Since the nails are flat, this is a harmless gesture. But this attack is followed by a quick forward thrust of the head and a very nasty bite may be inflicted by the sharp canines and the first premolars of the lower jaw. At times even the scraper is involved. During the attack the animal utters a querulous chatter. The truculence of the galagos seems to be directed solely toward humans. I have never seen them fighting among themselves. Even the young ones are independent and dislike handling, though they will tolerate a gentle rubbing of a finger along the jaw or behind the ears. The presence of several people does not disturb them providing no quick movement or noise is made. Completely fearless of humans, the twin galagos born in capitivity enjoy jumping on a shoulder or sitting on the top of someone's head.

The galago is as inquisitive as a monkey. Unlike that animal, however, curiosity manifests itself by smelling instead of handling the strange object. The galago will investigate the face and wearing apparel of even a total stranger. Anything new brought into the cage or enclosure is always smelled carefully.

I have attempted to show in another article (1939) that *Galago crassicaudatus*, when alone, and dependent upon humans for companionship, was a relatively affectionate animal which treated me much as it would a fellow galago. Without doubt the *Galago s. moholi* would be more demonstrative to humans were it dependent on them for companionship. It cannot be said, however, that this group of four display any real affection beyond their own circle. Their interest in me, I suspect, is due to the food I supply. As a group they play together in utmost harmony. They will pursue each other, roll about, and playfully grapple. At times they will hang suspended from a horizontal stick by their hind feet the while beating at each other with their free arms like two inverted pugilists. At feeding time it is a question of each galago for himself, although when the babies were beginning to eat and for a few months thereafter, their mother would sometimes give up part of her catch to a hungry young one who had jumped up beside her to help itself. Food in the possession of other galagos is much more attractive than any food in a plate. They will spend a great deal of time pursuing succulent morsels in the hands of one of their companions, even though similar morsels may be present for them. There seems to be no resentment on the part of the pursued if its prize is taken from it. The galago immediately proceeds to recapture the diminishing tid-bit.

Behavior of the Adults.

Although the behavior recorded in this section has been observed while the galagos were in the state of captivity, nevertheless the conditions under which they were kept have approximated, so far as is possible, their natural environment. Hence, I am justified in feeling that this general behavior does not differ fundamentally from that of the wild state.

Feeding.

Observations of this variety of *Galago* confirm the recorded statements that while they are insectivorous, they eat other things as well. Live moths,

grasshoppers and meal worms are great favorites. Milk, a constant in their diet, has never been refused. Vitamin B and cod-liver oil have been added occasionally to milk, especially after the birth of young. Sweetened fruit juices and melted ice cream are relished. Although water has frequently been placed before them, there is no evidence that they drink it. They will eat various kinds of thinly sliced raw vegetables and fruits at any time; more freely in the winter months when insects are difficult to obtain. They will also eat buttered bread or bread spread with honey in which wheat germ meal and rice coating flour are mixed. When cut flowers from the garden are available, such as bergamot and honeysuckle, they will bite off the heads, pull apart the petals and chew at their bases.

In the case of live food, as Geoffroy (1796) first recorded, the galago fixes its gaze intently on the insect. It never attempts to jump at it in mid-air; instead, it leaps up to a perch close beside the insect. Then holding on with its hind feet, the galago reaches out and grabs the moth with one or both hands. After putting the live moth in its mouth, it jumps away to a secure perch somewhat removed from its companions. Sitting up and holding the insect in one or both hands and closing its eyes to protect them from the frantic beating of the insect's wings, the galago begins at the head and consumes all but the wings. This is the same procedure which Cooke has recorded in the case of the *Tarsius* (1939). The wings are discarded by using the tongue to shove out over the scraper, which thus seems to be passively used as a trough. I have frequently placed moths in a wide-mouthed jar covered with a loosely fitting lid. The galagos quickly learned to push off the lid by using the tip of the nose. Standing up, stretched to full height, one will peer in and leap to the rim with all four feet bunched together. Then liberating the front legs but still holding on with the hind feet, the galago will dive in head first, locate and grab the insect with one hand and haul itself back by the power of its hind legs without loss of balance. Even when there is plenty of food flying about, the galagos tend to grab it from each other.

Vegetables and other inert food are always smelled carefully before sampling. If acceptable, the animal takes a small piece directly in the mouth, jumps away, and holding the morsel in one or both of its hands, bites off what it wants and drops the rest. Liquids are usually lapped up by the long tongue; at times, however, the hand is plunged into the fluid and subsequently licked dry.

Feeding takes place regularly. In the morning milk is placed in a shallow container close to the sleeping box. By the end of the day most of this has disappeared. At about 8 o'clock in the evening various foods and a second supply of milk are provided and left available throughout the night. The animals which have been active for some time are now hungry. They rarely consume a whole piece of vegetable or fruit; their habit is to take a few bites and drop the rest. In the morning the enclosure is strewn with fragments.

Throughout their active period, fecal elimination is very plentiful; the more so when they first become active at night. Urinary elimination is also plentiful and frequent, and usually independent of moistening the foot-pads, which has already been described. Though they rarely soil their sleeping box, they seem to have little further concern about the place for elimination. If handled during the day, they express fear or nervousness by immediate urinary and fecal elimination.

Grooming.

The galago is an unusually clean animal. Even its hands when soiled by food or foreign substance are carefully licked clean. General grooming involves the frequent use of the procumbent scraper, the tongue, and the oc-

casional use of the claw which serves as a scratcher for such spots, otherwise inaccessible, as behind the ear.

The chief grooming instrument, the procumbent scraper, long called the "comb," is used by the galago in vigorous action on his own pelt or on that of one of his companions. This action is a series of quick thrusts through the fur deep down to the integument. By this scraping action the animal can dislodge and remove any dead skin or foreign substance in the pelt (Lowther, 1939). The tongue completes the process of grooming with a thorough gentle licking.

Begun on first awakening, before the start of much activity, the grooming is repeated for short periods frequently during the active period. Grooming may be a mutual operation. I have seen two galagos grooming each other simultaneously; and two young ones may work on one of their parents at the same time. As for the action of grooming on the part of a galago of another species (*crassicaudatus*) with no companions other than myself, I have had personal experience. This animal frequently perched on my arm or hand and vigorously dug into my integument with its scraper as though I were a fellow galago. The intensity of the digging and scraping made it clear that any foreign object in the fur of a galago could be effectively removed. While the present variety of galago has not bothered to attempt much grooming of their mistress, the young ones occasionally have repeated the action of the former galago, particularly after licking off some sweet morsel adhering to my fingers. At times they have used the scraper perhaps to get off the last remnants of sweetness.

Calls.

The galago has several notes characteristic of different conditions, clearly differentiated but difficult to describe. 1. The alarm note; a shrill sound on a high pitch, which starts somewhat like a chipmunk's scolding note, though shriller, but which ends in a whistle. This note quiets the group into frightened stillness. 2. An automatic cry, the cause of which is unknown, and which may continue for an hour. It is a piercing noise with two pitches, high and low. While the animal is making this noise it will continue its activity, eating and jumping. It does not affect the others. 3. The low clucking note like the brooding hen, but on a lower register; used when annoyed. 4. The sex note, used by the male when pursuing the female. This is a soft questioning sound of two notes. 5. The conversational note; when separated, both male and female call to each other. This note is softer than the sex note but has the same two pitches, high and low. 6. A chattering note used by the female as an expression of annoyance at the attention of the male. 7. The maternal note; a very gentle, soft, caressing sound, used by the mother when talking to the young in the nest. 8. The squeak of the young; suggestive of young mice. It might possibly be called a squeaky chirp.

Sex Behavior.

The female of this form will accept the male only during periods of oestrus, which may last as long as five or six days. At this time she has a colorless discharge which perceptibly excites the male. He constantly smells her genitalia and just before the act of copulation the male is likely to lick the female with his long tongue. During the period of sex activity copulation has been observed to occur three or four times a night and it has also been seen in the morning when the animals would normally be sleeping. During the long periods between oestrus, the male continues his interest, although the female refuses to accept him. As he pursues her around the cage or enclosure, he utters a soft, plaintive call which I have described as the

"questioning sex note." At times the female merely keeps one jump ahead of the male and seems undisturbed by his attentions. If, however, they are continued for any considerable time, she finally turns upon him in annoyance with a chattering cry. This usually effectively discourages his attentions. Once, however, I saw the female become so angry, after chattering at the male without effect, that she turned upon him with such fury that he took to his heels in alarm. Generally speaking, the adult pair is a friendly and affectionate couple. They are frequently found perching side by side, grooming each other, wrestling and at times embracing (rubbing noses). During the period of pregnancy the female's disposition became far more truculent. The continued attentions of the male were repelled with increasing vigor and shortness of temper.

Nesting Habits.

The galago in the wild is in the habit of nesting in the hollow places among the tree-tops, according to E. Geoffroy-St. Hilaire, Pitman, Shortridge, and others.

E. Geoffroy, 1796:

"Ils nichent dans des trous d'arbres où ils préparent à leurs petits un lit qu'ils tapissent d'herbes."

Pitman, 1934:

"I have often come across the leafy beds these animals prepare for expected offspring at the bottom of hollows in trees."

Shortridge, 1934:

"*Galago moholi granti* is strictly nocturnal, sleeping during the day in hollow trees where it may generally be taken in small family parties."

In captivity, I have found that these animals show a tendency to tear up bits of available paper and to carry them into the sleeping box. While on the porch where a growing apple tree is situated, they bit off the ends of leafy twigs and carried these to the box up under the eaves of the porch roof. They would also gather bits of string, wool, heads of flowers and almost any other small soft object which happened to be loose. Just before the birth of young ones, the female was particularly active about the construction of a lining for the sleeping box. The galagos obviously prefer a darkened area in which to sleep during the day. Whenever a box was given them they used it rather than some secluded corner of the cage or porch.

F. Wood-Jones, p. 116 (1929) states that:

"Nest-building is a habit that is widespread among the Lemurs, and it occurs both in the species found in Madagascar, and in those living in continental Africa and in Asia. The curious Aye-Aye "Chiromys" builds an elaborate nest which has been described by Baron as a structure about two feet in diameter and entered by a hole in the side. Shaw has described the nest of "Chirogale milii" as consisting of "leaves and Dry Grass," and that of "Microcebus smithii" as resembling a bird's nest."

Breeding Season and Period of Oestrus.

Galago Activities.

When received in September, 1937, the female was immature. Ten months later (July 19, 1938), she experienced the first onset of oestrus. She did not become pregnant, however. After an interval of five months a second period of oestrus occurred (December, 1938) which resulted in the birth of twins four months later (April 14, 1939). Oestrus did not re-occur until

December 10, 1939, although the young stopped nursing sometime in July. At intervals of six weeks three additional short periods developed, and a fourth occurred twelve weeks later. A table of these data follows:

	Length of oestrus	*Result*
Female matured July 19, 1937	5-6 days	no fertilization
Second oestrus Dec. 15, 1937	5-6 days	twins (born Apr. 14)
Third oestrus Dec. 10, 1939	at least 3 days	no result
Fourth oestrus Jan. 22, 1940	at least 3 days	no result
Fifth oestrus March 7, 1940	?	no result
Sixth oestrus May 29, 1940	3 days	no result

** Oestrus recurred Dec. 7, 1940. See Appendix, page 461.

The only conclusions which can be drawn from these limited data are: 1. the period of gestation is four months; 2. a restricted season of sexual activity is indicated. Whether December normally initiates the sexual season in the wild state and the first expression of oestrus in July was atypical, or whether the latter is typical and the shift from July to December is an adaptation of the animals to their new environment, cannot be determined. In any event this evidence still indicates the time for the birth of the young is limited to the period between April and November. 3. It is also evident that like many other forms with a limited breeding period, in the absence of fertilization oestrus will reoccur at intervals, thus establishing the galago as poly-oestrus within the limits of their sexual season.

Comparison with Breeding Habits of Other Lemuroidea.

Zuckerman substantiates the conclusions that the moholi galagos, like the lemurs, have a restricted breeding season. He states that although the records are too few to place any definitive reliance on them, they nevertheless indicate that the breeding season is betwen April and September, with the majority of births taking place between April and June. He bases these conclusions on the record of seven births of *Galago s. moholi* which have occurred in the London Gardens between 1856 and 1927.

Donald Carter, mammalogist of The American Museum of Natural History, who recently returned (1938) from an expedition in South Africa, has made available to me his field notes and many specimens of *Galago s. moholi*, most of which were taken at Balovale, Northern Rhodesia, on the Zambezi River.

Between August 23 and October 15, Mr. Carter secured more than one hundred adults of which he brought back seventy-two to the museum. Two of the 29 females contained embryos, and one he noticed was nursing young. (He tells me that he did not record whether the remaining females were nursing). In addition to the adults 20 young galagos were brought into camp by the natives. The following is a digest of Mr. Carter's field notes concerning the young taken at Balovale:

August 23	1 pair shot, female nursing young
September 4	1 female with a single embryo
September 14	1 female with two fully formed embryos
September 18	2 newly born
September 20	1 young
September 24	2 young
September 26	4 young
September 27	3 young
September 28	2 young
October 1	2 young
October 10	2 young
October 15	2 young

An analysis of these data reveals that:

1. The relatively uniform dimensions of the adults indicate that they were at least a year old.
2. A comparison of the pelage and measurements of the young in the museum collection with those taken during the growth of the pair in my possession shows that the largest were not more than four or five weeks old.

Zuckerman (1932) states that three births among *Galago garnetti* occurred, one in May and one in June, 1930, and one in September, 1929, in the London Gardens. This corresponds with reports of births in the London Gardens among the true lemurs where only very exceptionally were there records of births outside the period March to June. Zuckerman states that, "All the sixty-six births occurring in the London Gardens Zoo were distributed in the period March to September, sixty-four between March and June, and two in September." Major S. S. Flower (1933) presents additional data which "provide a very good reason for arguing that species belonging to the genus *Lemur* have a demarcated breeding season. The following table showing the months in which 120 lemurs were born in the Giza Zoological Gardens confirms Zuckerman's opinion":

		Twins	Triplets
March	26 births		
April	42 births	3	1
May	32 births		
June	15 births		
July	4 births		
October	1 birth		
	120		

From this additional evidence it is conclusively established that the galago, like the lemur, has a restricted breeding season ranging from April to October, but that probably the galago south of the equator is more apt to have young in September and October than the lemur.

Zuckerman (1932) states that, "The breeding habit of the African members of the series Lorisiformes appears to be different from that of the Asiatic species belonging to the same subdivision of the Lemuroidea. Thus, the few available records regarding births in the genus *Galago* suggest that the animals belonging to this genus may have a restricted season, whereas the Hubrecht data for the slow Loris (Nycticebus coucang) prove that this animal breeds throughout the year." According to him, however, its curve of fertility seems to rise toward the end of the year.

Discussion of Environmental Causes of Oestrous Change.

An interesting article written by F. H. A. Marshall (1937) presents evidence that the reproductive rhythm may be influenced by extero-ceptive or other environmental influences, and that the oestrous cycle may be reversed in animals living in temperate climates after transference across the equator. He concludes that "among the insectivores, carnivores, rodents and non-ruminating ungulates with very few exceptions outside the tropical areas breed in the spring or first half of the year in the Northern Hemisphere." Also, "That they react to seasonal changes in a remarkable way is shown especially by those natural experiments in which animals of various species that normally breed once annually have crossed the equator and as a consequence have been induced to have two sexual seasons in one year." Marshall emphasizes the potency of more or less light as an activating factor. He further states that "Tropical and subtropical forms, however, such as antelopes (red and blue duiker) which live under comparatively uniform conditions as regards daylight, may have an extended breeding season or breed

all the year. They do not adjust themselves to the changing conditions of temperature in regard to sexual activity."

Following this analogy, could not the differences between the breeding habits of the lorises and the galagos be accounted for by a study of differences constant in their normal habitats? Since all these forms are nocturnal and tropical or subtropical, the value of more or less light as a breeding factor is not as important as conditions insuring a constant food supply, or other environmental influences. The *Galago senegalensis moholi* and *Galago crassicaudatus* and their subspecies live in the open savanna country where there is a prolonged dry season lasting from April through October, during which their young are born. The lorises, however, live in forested tropical regions where there are no such extremes of humidity and dryness and where a restricted breeding season would have no survival value. It would be interesting to determine whether *Galago demidoffii,* a small form found in the rain forest of Equatorial Africa in the very regions in which the duikers, cited by Marshall, live, would, like them, have continuous or irregular breeding season as a result of more uniform environmental conditions.

Period of Gestation.

As I have reported, the first period of heat, experienced by the young female under my observation, was not followed by pregnancy. The second period, however, which began five months later, proved to be a fruitful one. No peculiar conditions were noted for two months. The female then displayed increasing irritability at the attention of the male. She showed preference for the warmth of the radiator at the corner of the room and gave up jumping to high places. Her pelt became patchy between the shoulders. She looked thin and in bad condition. During the third month the female's irritation at the attentions of the male was so great that I separated them, giving each a cage. Paradoxically the female would answer the male's conversational note and seemed to enjoy talking to him from a safe distance. She showed enormous interest in food, eating very much more than usual, and seemed particularly fond of buttered bread. Since she refused cod-liver oil in milk, I smeared it on her fur, so that in licking it off she acquired an adequate dosage. During the intervals when both were liberated for exercise, the truculence of the female increased. A week before the birth of the young the female became very active in building a nest in her sleeping box. Tearing up pieces of newspaper, she carried them into the box. On the nights of April 12 and 13, 1939, she was unusually active.

Birth and Number of Young.

On the evening of April 14, I opened the doors of both cages to give the animals their customary exercise. The female was still in her sleeping box. On returning to the room a half hour later, I found her perched on the edge of the cage, holding in her mouth a dangling infant. All the while she was uttering a strange, protesting cry, directed at the male who had entered her cage and was watching the scene attentively. Obviously disturbed at his presence, the female jumped out of the cage onto a portiere and from there to the picture molding, her young one still clutched in her mouth. She finally made a downward leap of fully ten feet onto the bed, and from there retired to a dark corner of the room where she deposited the squeaking infant. I found a second young one clinging to the perpendicular side of the cardboard sleeping box. I cannot say just when the young were born. The pelage of one seemed still wet. The box was clean and there was no evidence of the placental membranes, which must have been eaten by the mother.

The birth of twins among galagos of this species seems to be a common occurrence, although single births do occur.

Donald Carter's field notes indicate that two young are frequently found in a nest, and Shortridge (1934, page 00) states:

"Twins seem to be of frequent occurrence. In Northern Rodesia—Ndola—several females were found carrying twins."

"A female in a Pretoria Zoo suckled two young ones. Another female gave birth to two young in October."

Haagner (1920, page 10) states that two is the usual number at a birth. There have been other instances, however, of gravid females containing but a single foetus.

Other galagos such as *crassicaudatus* and *crassicaudatus monteiri* are more likely to be carrying single foetuses (Pitman, 1934, page 159). This resembles more closely the habit of the Malagasy lemur where, as the statistics show (S.S. Flower, 1933) (*vide supra*, p. 451), among 120 births there were but three instances of the birth of twins and but one of triplets.

Post-natal Condition of the Young.

The young, male and female, were about the size of my index finger, and almost as slender. Their eyes were partly open. The tail was curled in a loose spiral, and they were sparsely covered with a homogeneous gray pelt.

The fact that the infant galagos were able to cling to the perpendicular surface of the box, and actually to stand on all fours shortly after birth, is of interest.

The young creep about, and after the first day or two of clinging to the mother with all four feet, they may be found under her, feeding, or in the nest. While they never cling to the parent as she moves about, frequently they will climb on her back or creep between her legs when she is crouched quietly in the cage. (Pl. VI, Figs. 15, 17). When in motion, however, they are either left behind, or she picks each up in her mouth, by the neck or the back, much as a cat would her kitten, and carries them about one at a time (Pl. V, Figs. 11, 12, 13). The passive infant accommodates itself to this treatment by drawing up its legs close to the body (Pl. V, Fig. 12).

Donald Carter reports that the young *Galago s. moholi* brought in by the natives were found in the nests and never found clinging to an active parent. These observations are at variance with those recorded by Shortridge (1934) and Haagner (1920) in the cases of captive animals in the Zoological Gardens of South Africa. Shortridge states:

"The young cling to the under side of the mother and are carried about in this manner until more than half grown, the mother being much hampered in her movements, when the young become larger."

Haagner states (p. 19):

"They cling to the mother like the young of the ordinary Ringtail Lemur and South American Marmosets, and ride on her back or hang underneath her as opportunity offers."

These statements by Shortridge and Haagner imply that the mother jumps about with the young clinging to her ventral surface or her back. Careful observation of the family under discussion has never disclosed any such action. When feeding the young are on their backs on the floor of the cage and the mother remains quietly in one position. To be sure, the young do cling to the under surface of the mother by their front legs, but the hind legs are always free and protruding beyond the body of the mother. They may also be found sitting on her back (Pl. VI, Figs. 15, 16) or later on the father's back, but this is only when the animals are quiet or sleeping.

There never is any clinging action (as Haagner has suggested) such as one finds among the monkeys when the parent is active or jumping about. Shortridge's statement about the mother's being much hampered in her movements is misleading. She obviously could not move when the young were nursing, and during activity they were never attached to her in any way, unless she decided to move them by carrying them in her mouth.

In contrast with these findings, however, F. Wood-Jones[5] and P. L. Sclater[6] both describe the mother of the genus *Lemur* as the passive agent, the young clinging to the ventral surface of the parent, and using its own tail to help hold itself on to the parent body. The young lemur therefore is the active agent.

Hill, in 1937, described the birth of twins of the slow loris (*Nycticebus tardigradus*). He writes that the young are sturdy and that the mother placed them on the ground at the very beginning. He does not state how the mother carried them about, but implies that she does the carrying, and the young are passive.

Hill, 1937, page 388:

"She will rush toward the baby and pick it up if danger threatens, and place it down again when the risk is over. She will leave her food to do this. If the baby is marooned, it squeaks for its mother, and she will try to get to it, if she is able. If the baby is picked up for observation and replaced, she has not discarded it, but smells it, licks it clean, and allows it to go to sleep again."

Cuming, in 1838, described the habits of a *Tarsius* with her young which seems to have a striking similarity with *Galago s. moholi*. He states that the young when born have their eyes open, are covered with a good pelt of fur, are able to creep around the cage shortly after birth, and the parent carries the young around, in the mouth, just as in the case of *Galago s. moholi*.

H. Cuming, 1838, page 68:

"The young appeared to be rather weak, but a perfect resemblance to its parent; the eyes were open, and the body covered with hair; it soon gathered strength, and was constantly sucking betwist its parents legs, and so, well-covered by its mother, that I seldom could see anything of it but its tail; on the second day it began to creep about the cage with apparent strength and even climb up to the top by the rods of which the cage was composed. Upon persons wishing to see the young one covered over by the mother, we had to disturb her, upon which the dam would take the young one in its mouth, in the same manner as a cat, and carry it about for some time; several times I saw her when not disturbed trying to get out of the cage, with the young one in her mouth as before. It continued to live and increase in size for three weeks, when unfortunately some person trod upon the tail of the old one, which was protruded through the cage, a circumstance which caused its death in a few days; the young one died a few hours after, which I put into spirits."

Le Gros Clark (1924), however, does not corroborate this observation with relation to the *Tarsius*. He states that:

"I have kept under observation several female Tarsiers and young and have never been able to confirm this" . . . (carrying of the young by mother in mouth). "The young cling to the fur of the mother's abdominal wall, grasping with both hands and feet, and are not in any way held by the mother. In this way the little animal is very often wholly concealed from view when the mother is in a resting position, clinging to a branch"—He further states that: "At birth the Tarsier has reached a comparatively advanced stage of development. The eyes are open, and though its movements are uncertain, the animal can cling to a vertical branch, and scramble about the branches in a hesitating way. When disturbed it assumes an appearance of alertness."

[5] Wood-Jones, 1929, page 115. "Lemurs do not nurse or handle or carry their young ones, for it is not the mother that clasps the offspring, but the offspring that grips the mother."

[6] P. L. Sclater, 1885, p. 672. "Young lemur lies nearly transversely across the belly of its mother, and, passing its long tail around her (mother) back and so on to its own neck, uses it as a prehensile organ to hold on by."

Nursing and Care of the Young.

The female has two pair of mammary glands. Those of the anterior are so laterally placed that each lies practically on a line with the inner border of the arm. The inguinal pair lie closer to the median line. During the first two days the young clung to the mother by all four feet. I saw one nursing from a pectoral mamma while its body was attached transversely under the mother's arm and around onto her back. Within a few days, however, they began to stretch out on their backs in the nest, gripping the mother with their front feet, while their hind feet protruded grotesquely from under her body. Occasionally they would give a convulsive kick. At first the young were so small that the mother had no difficulty in covering all but their protruding legs with her own body. As they grew larger, however, she was obliged to lift herself more and more to accommodate them, causing her front legs to be bowed over them in a ludicrous fashion. Finally they grew so large that she could accommodate only one at a time.

During the period of nursing, which lasted three and a half months, the mother displayed an enormous interest in food. Her consumption of milk was more than twice as great as before pregnancy. And she would now even tolerate in it cod-liver oil, which perceptibly improved her pelage.

The mother kept the young clean by grooming their fur herself. At their nursing time, while they were lying on their backs, with hind legs extended, she would lick clean their genitalia.

During the period of nursing the mother's urine carried the odor of sour milk.

Parental Attitudes.

The mother galago displayed great solicitude for her young. When they were taken out for inspection, she would go to the length of jumping close to and even brushing my arm in her agitation. When the young were put down, she promptly gripped one in her teeth by the neck and jumped to the cage, using the pendant youngster instead of her nose to lift the cage door. Having recovered one infant, she then proceeded to rescue the second, in a similar manner. A thorough licking and smelling of the young followed their return to the nest. During the first three weeks the male was kept in a separate cage except during the periods of exercise. He seemed restless and curious about the occupants of the other cage, eating relatively little and keeping his eyes glued on the activities across the room. When liberated for exercise the male invariably made his way to the cage and tried to open the then locked door. The mother, permitted to exercise with the male, seemed glad of her freedom and was willing to play to some extent. When the young were three weeks old the galagos were all placed in the same cage without ill effects.

Perhaps the separation of the parents was an unduly cautious move, but the circumstances seemed to warrant this action. For the first few weeks the mother made very soft caressing sounds to her young and they were frequently heard making small mouse-like squeaks. As the infants grew, the mother continued and the father assumed solicitous attitudes, and even up to the age of nine months they obeyed the call of the mother. During the summer months when the family occupied a screened-in porch, I often heard and watched the mother give the signal for the hour of retirement after a night's activity. Just before sunrise, she would start a soft, conversational note and the young as well as the mature male would answer her call and immediately jump to her side. Within five minutes all four would have retired into the sleeping box for the day's rest. The action of the mother indicates a greater sense of responsibility toward the young than that of the father. It is she who warns the group of any danger. When a

cat lurked on the steps leading to the porch, it was the mother who gave the alarm call ending in a shrill whistle, which warned the family and sent me on a tour of investigation. In the winter the family was moved to a large enclosure in the college greenhouse, where a shelf has been made into a sleeping box by the addition of a sliding door in which an aperture has been cut. For several minutes the family jumped and climbed and smelled about this new region. It was the mother who located the small aperture of the sleeping box and the dark quarters within. And after investigation it was she who began the conversational call which brought father and children to her side. The entire family is affectionate. The mother frequently caresses the young even though they are now more than a year old.

The maternal solicitude continued unabated and even when they were far too heavy to be carried, (up to 3 months), she still tried to lift them in her mouth and to get them back into the nest when the young were molested. After handling, also, she would lick them solicitously.

Development of the Young Galago.

From the beginning, as has already been stated, the young galagos could cling to surfaces and walk about on all fours. When not nursing, they were either under the mother, on her back (Pl. VI, Figs. 15, 16), or were curled up in a little nest made for them of soft tissue. In two weeks time there was a perceptible increase in size. Their pelt was heavier, but still homogeneous in color. They not only could walk about, but had begun to take small leaps of four and five inches, clumsily trying to balance on their hind legs, making efforts to climb on the struts of the cage and even to jump a few inches. Their bellies were very fat and their tails still curled somewhat. Between the second and third weeks, the young ones began to use the tongue in licking and grooming each other; they even began to lick me. When three weeks old they were approximately twice their original weights. They had minute incisor and canine teeth. They were very playful and would nip each other's tails and frolic about.

When four weeks old they could jump from the side of their cage a foot or more to its floor and back again. They could walk along a horizontal bar about a half-inch in diameter, sometimes losing their balance, but never their grip. They would now play with each other like kittens and could stand on their hind legs although their balance was still uncertain.

At six weeks the fur had become adult in appearance, the end of the hair assuming a lighter color, giving a frosted look. The chest and the lateral surfaces of the legs and arms were light orange-yellow. The longer, darker hairs standing out on the back, which are characteristic of the adult, were more conspicuous in the young ones, like a soft black fuzz. The dark markings on the face, however, were not yet as evident as those of the adult. At this time they began the moistening of the hand and foot-pads. They made great work of this operation, rubbing with energy the palm of the hand onto the sole of the foot on the same side. They scrubbed for some time, and were not completely sure of their balance.

The young galagos, which could jump from two to three feet in a horizontal position, watched with interest the action of their parents as they made vertical leaps from a window-sill and portiere to the picture molding. The first attempt at a vertical jump like those of the parents was made at the age of seven weeks when one succeeded in reaching the top of the window trim. One of the parents immediately jumped to a position beside it, and licked its fur. By the eighth week the young ones began coming down a perpendicular surface, gripping the edge in a regular adult fashion. At this time the young began making the protesting adult growl when handled. By the end of the second month, their balance was greatly improved and they could stand upright with considerable confidence.

From the age of one month the young attempted to eat solid food which was placed in the cage for the mother. By the end of the second month they were eating solid food regularly and drinking milk in considerable quantities.

Although still nursing, they were now so large that they had to be fed one at a time. By this time, the galagos had been moved into the country, and now occupied a screened-in porch, with freedom of action during the entire night. Flying moths were included in the diet of the parents. While at first the young had little interest in these flying insects, it grew as they watched the eagerness of the parents. They did not attempt to catch any themselves, but as the parents caught a moth, the young would try to take it away. The mother seems fairly willing to give up portions to her offspring. The samples were evidently pleasant, and by the twelfth week the young ones were capturing their own moths. They were not yet as quick or as dexterous as their parents, and even after succeeding in a catch, they frequently were obliged to give up their prize to a hungry parent. Picking up the discarded wings, the young would chew on the base of these for what nourishment there might remain. Cooke (1939) notes that adult *Tarsius* also chew on the base of moth wings. At three months of age they had learned to balance themselves on the rim of a jar and to dive in and extract the fluttering insect without loss of balance. By the end of the third month, the young had stopped nursing. The only evidence of infancy was the tendency to take moths from the mother, which she continued to permit them to do. They were now less rotund, and except for the soft black fuzz on their backs they looked like their parents in miniature.

Sleep.

During sleep these animals have a tendency to crowd together, one frequently sleeping on top of another. In cold weather it is not unusual to find one adult completely hidden by a companion. They protect their eyes from the light by burying the head in the pelt of another galago. If the light is too intense, they try to crawl under any movable object for protection. At times, too, the tail is wrapped over the eye to exclude the light.

This variety does not usually sleep with the neck arched and the head tucked between the hind legs as does *Galago crassicaudatus*, although on rare occasions, when one *Galago s. moholi* has been isolated, I have seen this method employed. The large membranous ears remain somewhat folded during sleep.

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Appendix.

The activities outlined here occurred after the manuscript was in type.

On the evening of December 7, 1940, oestrus recurred after an interval of six months. At this time a new factor was introduced. For some weeks prior to this date the young male, now twenty months old, had given evidence of sexual maturity with the result that, at the onset of oestrus, both males were accepted by the mother. The young female, however, has not yet become sexually active.

EXPLANATION OF THE PLATES.

Plate I.

Fig. 1. Head of adult male enlarged 2 ×. Crescent-shaped rhinarium shown with deep median cleft. Upper lip bounded by fur. No "snarling" expression of upper lip though animal is angry. Eyes with vertical pupils. Lashes visible on upper lid of eye to right. Vibrissae evident lateral, median to and below the eye, also at side of mouth on left. Note method of grasping small stick. Thumb and index finger on one side, the three outer fingers on the other.

Plate II.

Fig. 2. Life size group of family of four in characteristic sleeping position, taken when young were a year old. Note corrugation of ears of animals to right and lower center.

Fig. 3. Photograph of family on rafter under porch roof. Upper eyelids of animal third on right shown extended over bulging eyes. This galago had been perched on the rim of the flash light reflector and was looking at the bulb when it was discharged. For a short time the animal was unable to tolerate even a subdued light.

Plate III.

Fig. 4. Photograph of hands ×2. Illustrates method of resting palm on a flat surface with the flexed digits somewhat bent to one side. Note flat nails and pads along under surfaces of digits ending in enlargements at tips. Interdigital pads shown protruding beyond palm of hand to left.

Fig. 5. Phalanges of hand flexed for grasping food. The two distal phalanges bend over the proximal phalanx of each digit except that of thumb. Thumb opposed.

Fig. 6. Photograph of under surfaces of hand and foot, taken from the inside of a glass door on the outerside of which a galago is clinging. The index finger is shown to lie almost midway between the large space which separates the thumb and third finger. Illustrates the way in which the pads of the palm and sole flatten out when applied to a flat surface.

Fig. 7. Photograph of under surfaces of feet taken when animal was in same position as in Fig. 6. The pads of the soles are not flattened out. Note fur-covered hinder portion of ventral surface of foot and large size of the pads of hallux, the interdigitals, thenar and hypothenar.

Plate IV.

Fig. 8. Photograph showing method of grasping branch by feet alone, leaving hands free for feeding.

Fig. 9. The animal is hanging head down with hands free, grasping screen-trim by hind feet. Note the widely abducted, powerful hallux.

Fig. 10. Adult male and female. Male standing on toes reaching for insect. Note length of foot and hind limb. Tail serves as balancing structure. Digits of the hands are somewhat flexed, which is their usual position unless grasping food or perching.

PLATE V.

Figs. 11, 12, 13. Method of carrying young. (Fig. 11). Mother while on table-top grasps young in region of shoulder. (Fig. 12). Young lifted from table, mother poised to jump to floor; feet of young drawn up. (Fig. 13). After jump, mother depositing young on floor.

PLATE VI.

Fig. 14. Photograph of young when two weeks old.

Figs. 15, 16, 17. Different postures when awakened from sleep. Young are about five weeks old. (Fig. 15). One baby under the mother, trying to get away from the light while the other lies on top of parent.

(Photographs reproduced as Figs. 1-10 were taken by Agnes Townsend; Figs. 11-17 enlargements of 16 mm. motion picture film taken by author).

FIG. 1

A STUDY OF THE ACTIVITIES OF A PAIR OF GALAGO SENEGALENSIS MOHOLI IN CAPTIVITY INCLUDING THE BIRTH AND POSTNATAL DEVELOPMENT OF TWINS

FIG. 2.

FIG. 3.

A STUDY OF THE ACTIVITIES OF A PAIR OF GALAGO SENEGALENSIS MOHOLI IN CAPTIVITY, INCLUDING THE BIRTH AND POSTNATAL DEVELOPMENT OF TWINS

FIG. 4.

FIG. 5.

FIG 6

FIG. 7.

A STUDY OF THE ACTIVITIES OF A PAIR OF GALAGO SENEGALENSIS MOHOLI IN CAPTIVITY, INCLUDING THE BIRTH AND POSTNATAL DEVELOPMENT OF TWINS

FIG. 8.

FIG. 9.

FIG. 10.

A STUDY OF THE ACTIVITIES OF A PAIR OF GALAGO SENEGALENSIS MOHOLI IN CAPTIVITY.

FIG 11.

FIG. 12.

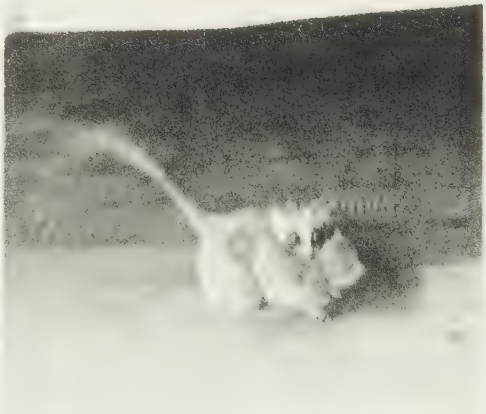

FIG. 13.

A STUDY OF THE ACTIVITIES OF A PAIR OF GALAGO SENEGALENSIS MOHOLI IN CAPTIVITY, INCLUDING THE BIRTH AND POSTNATAL DEVELOPMENT OF TWINS

FIG. 14.

FIG. 15.

FIG. 16.

FIG. 17

A STUDY OF THE ACTIVITIES OF A PAIR OF GALAGO SENEGALENSIS MOHOLI IN CAPTIVITY, INCLUDING THE BIRTH AND POSTNATAL DEVELOPMENT OF TWINS

28.

Diets for a Zoological Garden: Some Results During a Test Period of Five Years.[1]

HERBERT L. RATCLIFFE

Advances in animal nutrition have not been applied extensively to feeding problems of zoological gardens. Yet many of the difficulties inherent in maintaining health and vigor of wild animals in this environment probably could be solved in terms of information available either for related domesticated species or for man. Presumably adequate substitutes for natural foods would permit both the exhibition of more nearly normal animals and the maintenance of breeding colonies of many species. The economic aspects of either of these results are obvious.

During the first quarter of 1935 new diets were introduced at the Philadelphia Zoological Garden. For more than ten years before this time feeding practices had not changed materially. Therefore to aid in planning new formulae, records of mammals and birds that had been autopsied from 1924 to 1934 were reviewed for definite or presumptive evidences of malnutrition. Estimates of deficiencies, obtained by this review, were substantiated by comparing the values of foods that had been available to these wild specimens with those necessary to meet the known requirements of the nearest related species, whether man or domesticated animal.

Thus far, three mixed rations have largely replaced the various combinations of foods that had been used. One of these, with supplementary fruits and vegetables, is fed to the so-called omnivorous mammals and birds. A second, with mixed timothy and clover hay, provides for the herbivorous mammals. A third is a complete diet for the greater number of the Carnivora. This system includes neither fish-eating mammals and birds, nor specialized insectivorous animals.

The degree to which requirements have been met by these diets may be estimated at the present time only by changes in the causes of death, the death-rate, the birth-rate and the development of the offspring. More exact standards have been precluded to a large extent by conditions under which this study was conducted and by the types of animals involved.

Because of the great number of species represented in this collection, changes in the causes of death may be considered more completely only when more extensive material has been accumulated. But within the five-year test period just passed, changes in death rates, birth rates and in the development of young of several animal groups seem to justify the conclusion that these food mixtures have been reasonably successful. Increasing interest in certain wild animals as experimental subjects and requests for information on feeding them, suggest that some of these observations may interest others than those immediately concerned with the management of zoological gardens.

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[1] From the Penrose Research Laboratory of the Zoological Society of Philadelphia and the Department of Pathology of the University of Pennsylvania.

At the present time, discussion must be limited to the reactions of certain species of animals and birds as members of relatively large taxonomic groups rather than as individuals. These groups, as such, are believed to have had approximately equal opportunity for breeding before and since the diets were changed. Exposure to morbid influences also has been equal, except of course, as modified by diet, or, in some instances, by reduction of the number of individuals within enclosures.

Omnivorous Animals.

The ration designed for this rather indefinite class of mammals and birds is made up of 1 part of ground, boiled horse-meat and 9 parts of the following mixture:

Rolled oats	20 per cent.
Whole wheat meal	20 " "
Soybean oil meal	20 " "
Peanut oil meal	10 " "
Yellow corn meal	10 " "
Buttermilk (dry)	5 " "
*Brewer's yeast (dry)	5 " "
Alfalfa leaf meal (dehyd.)	5 " "
Oyster shell flour	2 " "
Iodized salt	2 " "
**Cod-liver oil concentrate	1 " "

These materials are mixed in bulk and used as needed. The ration usually is prepared the day before it is fed. First the ground meat and the dry materials are mixed thoroughly, then enough meat broth (water in which the meat is boiled) is added to form a stiff mash. This is pressed into shallow pans of convenient size and refrigerated overnight at 44 to 46 degrees F. after which it has hardened sufficiently to be cut easily into pieces appropriate to the size of the animals.

Allowing for natural variation in foodstuffs the approximate composition of this ration is:

Protein	25	per cent.
Fat	5	" "
Carbohydrate	45	" "
Calcium	1	" "
Phosphorus	0.5	" "
Iodine	0.017	" " (potassium iodide in "iodized salt.")

Energy value=3 calories per gram.

A variety of materials has been included in this ration with the intention of offering a palatable food of which animals would not tire quickly. The sources of protein are varied and the mineral and vitamin content have proved adequate for growth and reproduction except in instances that will be mentioned later. Obviously the formula may be varied and other substances added or substituted for those now in use.

Subhuman Primates. Thus far, animals of the following genera have been available for observation: *Gorilla, Pan, Pongo, Hylobates, Cercopithecus, Erythrocebus, Macaca, Theropithecus, Papio, Mandrillus, Saimiri, Cebus, Lagothrix, Ateles* and *Lemur.* Some of these generic groups contain relatively large numbers of species of which few have been represented in

* Brewer's Blended Dried Yeast. 1938 assay claims 30 international units of vitamin B_1 and 15 Sherman units of vitamin B_2 per gram.

** Assay claims: 3000 U.S.P. units of vitamin A and 400 A.O.A.C. "chick" units of vitamin D per gram.

the collection. With the exception of rhesus monkeys (*Macaca mulatta*), these animals are kept in heated quarters during cold weather, and have little exposure to sunlight except in summer.

Prior to 1935, more than half the total diet of these animals consisted of polished rice, boiled sweet potatoes and bananas. Green foods, citrus fruits, milk and eggs, were fed in significant quantities only to anthropoid apes (Corson-White, 1922).

Since 1935, about one-half the energy intake of subhuman primates of all ages has been supplied by the mixed ration, and, with exceptions to be noted, the remainder of their diet made up of uncooked fruits and vegetables: sweet potatoes, carrots, apples, bananas, citrus fruits and green vegetables. In addition to these food stuffs, anthropoid apes also receive from 1 to 4 liters of fresh whole milk each day. The two gorillas now in the collection also are fed about 200 grams of uncooked ground horse-meat each day, and an equal quantity of boiled horse liver 3 or 4 times each week. Pregnant and lactating females and immature animals of all types are given from 0.5 to 2 liters of a milk and egg mixture (1 egg per liter) and 5 to 20 cubic centimeters of a preparation containing some 800 units of vitamin A and 250 units of vitamin D per cubic centimeter.

This diet, mixed ration and fruits and vegetables, is estimated to supply at least 10 to 12 per cent of protein, 3 to 4 per cent. of fat and 30 to 40 per cent. of carbohydrate. Because of the relatively small amounts of calcium and phosphorus contained in vegetables and fruits the percentages of these materials in the mixed ration is reduced by at least half in the total diet.

The known daily energy needs of man and lower animals permitted the assumption that food requirements per unit of body weight would vary widely with the several species of subhuman primates in the collection. In consideration of size and spontaneous activity, allowances of 100 to 200 calories per kilogram of body weight per day did not seem excessive. In actual practice, however, amount of food taken may vary widely from day to day, and dominant members of a group must always be overfed so that others will be allowed adequate amounts of food. Also, frequent feedings[2] seem to be the most economical method of maintaining this type of animal, lessening waste and preventing overeating of any one food with subsequent loss of appetite for that or other substances. To accomplish this best, the keeper must return to the cages two or three times.

Table I is a summary of breeding and mortality records for each of the five years preceding and following the change of diet. "Total Stock" listed in the first column of the table includes all animals because records do not permit separation of potential breeding stock.

[2] Feeding schedule developed with the aid of Mr. M. I. Tomilin.

Monkeys	8:30 A.M.	Mixed ration (except on Sunday)
	11:30 A.M. to 12 M.	Green leafy vegetables
	2:30 P.M. to 3 P.M.	Sweet potatoes and carrots
	Offer water twice daily.	

From 4 to 16 ounces of mixed ration with 2 to 3 times these weights of vegetables will be required. Amounts are determined by size of the animals.

Chimpanzees and Orangs	8:30 to 9:00 A.M.	Oranges (from October to May because of cost)
	9:00 to 9:30 A.M.	Whole milk
	11:00 to 11:30 A.M.	Green vegetables
	1:00 to 1:30 P.M.	Water
	1:30 to 2:00 P.M.	Sweet potatoes and carrots or tomatoes
	3:30 P.M.	Whole milk
	4:30 to 5:00 P.M.	Mixed ration except on Sundays when bananas are substituted
Gorillas	Feed according to the schedule for Orangs and Chimpanzees except that from 11:30 A.M. to 12 M. they receive raw ground horse-meat every day, and from 3:30 P.M. to 4 P.M., three or four times a week, each receives boiled horse liver.	

TABLE I.

Records of Births and Deaths for the Subhuman Primates at the Philadelphia Zoological Garden During Each of Five Years Before and Five Years After the Diet Was Changed.

Year	*Stock*		*Acquisitions*	*Births*	*Deaths*	*Sales*
	♂	♀				
1930	58	48	27	5	51	0
1931	48	39	21	2	19	0
1932	49	42	8	3	15	1
1933	48	38	9	3	11	0
1934	46	41	11	5	18	0
1935	45	40	30	6	17	15
1936	43	46	19	6	8	19
1937	34	53	13	5	7	4
1938	35	59	8	7	14	19
1939	28	48	9	12	5	0

From 1930 to 1935 the average annual birth rate was 1 for 11.6 females. This increased to 1 for 6.6 females after the diet was changed. Prior to 1935, breeding was limited to a few species of *Cercopithecus* monkeys, mainly *Macaca mulatta,* and to Orang-utans (*Pongo*) and Chimpanzees (*Pan*). All infants that survived breast feeding to the age of 12 to 16 weeks developed rickets.

With the present diet, *Macaca irus, M. mulatta, Cercocebus fulginosus, Cercopithecus sabeus, C. grivet, C. mozambicus, Cebus fatuellus, Papio papio,* and *Pongo pygmaeus,* have bred about as frequently as may reasonably be expected. Except for an occasional death that could not be attributed to mulnutrition, all offspring, except those of *P. papio,* the Guinea baboon, have developed normally. These baboons, of which there have been five, developed rickets, however. All of them were born in the autumn, as were many of the others, and had little exposure to sunlight. They recovered promptly with appropriate artificial feeding. Possibly the greater vitamin D requirement of the baboon will prove to be characteristic of the type and may be related to the rapid growth of the facial bones to form the typical dog-like features; for it is in this part of the body, rather than in the thorax and extremities, that abnormal bone formation first appears.

Also to be noted in Table I is the reduction in the number of males in proportion to females in the colony. Breeding possibly has been influenced by this change, but the death rate was not materially affected. Injury by cage mates has contributed little to mortality rate at any time, although occasional losses from this cause occurred throughout the period. The average yearly death rate of 12 per cent. from 1935 to 1940 is to be compared with that of 25 per cent. from 1930 to 1935.

This diet for subhuman primates is based to a considerable degree upon recognized requirements of man, especially as to vitamins and minerals. It is essentially a modification of the diets suggested for these animals by Corson-White (1931) and by Tinklepaugh (1931, 1933) but is less complex than either of these. In consideration of the known food habits of the species of subhuman primates available for study it seemed that their dietary needs might be met adequately by using a mixed ration composed of easily available foods for domesticated animals. This has given an economical and palatable mixture which, combined with accessory foods, seems to be a reasonably complete diet. An obvious fault possibly is the low fat content, but thus far there is no indication that this is an important lack.

Whatever criticisms may be offered to this system of feeding, it seemed reasonable to assume that the mixed ration with some of the supplements also would meet the requirements of many other species of mammals and

birds. In deciding upon the relative amounts of mixed food, vegetables and fruits for these animals, preferences as well as presumed needs, as indicated by experimental studies of diet, field studies of food habits and the structure of the intestinal tract, have served as guides.

Other Mammals. The mixed ration that has been described constitutes from 50 to 60 per cent. of the diet of rodents of the following genera: *Glaucomys, Sciurus, Citellus, Hystrix, Erethizon, Dasyprocta* and *Neotoma.* Supplementary foods are apples, carrots, sweet potatoes and green vegetables. This diet, the mixed ration and vegetables, also forms from 60 to 70 per cent. of the intake of the bears (Ursidae) and raccoons, coatis and kinkajous (Procyonidae). Horse-meat and fish supply the remainder of their intake. The present quarters for these animals do not favor breeding, but as judged by appearance, activity, growth of fur and postmortem examinations, the diet seems adequate for growth and maintenance.

Birds. A large number of species of so-called seed- and insect-eating birds, Passeriformes, many of the parrots, Psittaciformes, all Columbiformes, Galliformes, and Anseriformes, are fed one diet, the chief element being the mixed ration that was developed for the apes and monkeys. This food makes up about 70 per cent. of their intake. Supplementing it are green vegetables, sprouted grains and fruits. In view of the known food habits of many species of Passeriformes, the mixed ration is probably too low in fat content to be completely satisfactory, and it has proved to be unsuited for unfeathered young of local species of this order. Further investigation is necessary to determine whether or not a special diet for the adults of this order is economically justified. During the present test period these birds have shown noteworthy improvement in plumage colors, and lessened morbidity and mortality.

Breeding as a measure of the adequacy of the diet must, however, be limited to birds of the families Phasianidae and Anatidae, for few others are exhibited under conditions favorable to this activity. Prior to 1935, about 70 per cent. of the intake of these two families consisted of a mixture of equal parts of cracked corn and wheat screenings, supplemented by green vegetables. Crushed limestone and oyster-shell were supplied ad libitum to the pheasants.

Phasianidae. The pheasants, junglefowl and larger varieties of quail are exhibited in pens that provide from 150 to 200 square feet of floor space. Small types of quail have less space while wild turkeys are exhibited in a much larger pen, and peafowl are at liberty on the grounds. Visitors may pass within a few feet of all enclosures. From two to seven pheasants of one species, with one adult male to the group, occupy each pen. Junglefowl, turkeys and quail are kept in small flocks in which there may be more than one male.

From 1930 to 1935, breeding in this group was limited chiefly to silver pheasants (*Gennaeus nycthemerus*) but occasional young were produced also by Swinhoe's pheasant (*Gennaeus swinhoii*), junglefowl (*Gallus gallus*), the common peafowl (*Pavo cristatus*) and stubble quail (*Coturnix coturnix*).

Since the present diet was offered, five species of pheasants have produced fertile eggs regularly, but none has had greater than 15 per cent. fertility. Compared to this is the fertility rate of more than 50 per cent. for wild turkeys and three species of quail. But in spite of the relatively unfavorable conditions under which these birds live, the number of young produced by this group from 1935 to 1940 was four times greater, in proportion to the breeding stock, than from 1930 to 1935, and the annual death rate fell from 38 to 24 per cent.

Anatidae. Many of the members of this family are exhibited in one body on an artificial pond. Others are kept in smaller enclosures along a

stream. The mute swan, (*Cygnus olor*), is the only species provided with a separate space where the pair may nest. In all locations visitors may approach within a short distance of the birds.

From 1930 to 1935, breeding was limited to Canada geese, (*Branta canadensis*) and mallard ducks, (*Anas platyrhynchos*), which hatched an average of twelve young per year. With the present diet these continue to breed and, in addition, mute swans, (*Cygnus olor*), and upland geese (*Choephaga magellanica*) have produced young regularly, and blue geese (*Chen coerulescens*) and Egyptian geese (*Alopochen aegyptiacus*) have occasionally nested. From 1935 to 1940, an average of 43 young were hatched each year. Young birds of both the family Anatidae and Phasianidae are fed the mixed ration with about 10 per cent. of finely chopped green vegetables. Growth has been entirely satisfactory and loss negligible. This diet for Phasianidae and Anatidae corresponds in all essentials to that developed by Callenbach, Murphy & Hiller (1932) for ring-necked pheasants. More recent experimental studies of the nutritional requirements of chickens, pheasants, turkeys, ducks and geese, (Barnum, 1935), (Baird & Green, 1935), (Bethke, Record & Kennard, 1936), (Norris, Elmore, Ringrose & Bump, 1936), (Milby & Henderson, 1937), show that the food supplies all necessary elements in adequate quantities, especially those essential to high fertility and good "hatchability."

Breeding of both Phasianidae and Anatidae probably has been limited more by small enclosures, crowding by other species and by disturbances of visitors than by any other factors. Pheasants should have larger pens, and geese and swans probably should be separated in pairs for the best results.

Herbivorous Animals.

The composite ration used for herbivorous animals contains beet pulp, chopped vegetables and a portion of the following dry mixture:

Brewer's grains (Dry)	400 lbs.
Yellow cornmeal	200 lbs.
Crushed oats	200 lbs.
Soybean oil meal	200 lbs.
Alfalfa meal (Dehyd.)	100 lbs.
*Brewer's yeast (Dry)	40 lbs.
Oyster-shell flour	40 lbs.
*Iodized salt	10 lbs.
*Codliver oil concentrate	5 lbs.

This mixture also is prepared in bulk for use as needed. The ration is made up in the late morning and fed in the early afternoon. The beet pulp is wet with an approximately equal weight of water and soaked for 1 to 2 hours. An amount of the dry mixture equal to the dry weight of the beet pulp, and chopped cabbage or carrots in an amount about equal to 10 per cent. of the total dry weight, are added and the whole well mixed. This forms from 60 to 70 per cent. of the diet of the herbivorous animals. The remainder is obtained from mixed timothy and clover hay. With different species of herbivorous animals the feeding allowances of the mixed ration vary between 10 and 40 grams per kilogram of body weight, or 1 to 4 pounds of the completed mixture per 100 pounds of body weight.

The approximate composition of the completed ration is:

Protein	15	per cent.
Digestible protein	11.5	" "
Total digestible nutrients	70	" "
Calcium	1.16	" "
Phosphorus	0.25	" "

* See formula for omnivorous animals.

This mixture is a modification of rations that have been developed for cattle and sheep (Morrison, 1939). In view of the type of hay available, the protein content is lower than that usually recommended. But the problem here is simply one of maintaining breeding stock in good condition. Neither milk production nor rapid gains in weight are considerations. Beet pulp is used as palatable diluent because concentrates are not tolerated well by deer in captivity. Vegetables are included also for palatability. The cost of the mixture compares favorably with others that provide equal amounts of digestible nutrients with smaller numbers of constituents.

Artiodactyla. The majority of herbivorous animals that have been available for study are included in the families Cervidae, Bovidae and Camelidae of the order Artiodactyla. Some species of cervines and bovines always have bred in the garden. Hence consideration will be given mainly to these groups.

All of the deer, Cervidae, except delicate tropical species such as the barking deer, *Muntiacus muntjak,* all of the Camelidae and the hardier Bovidae, are kept in open paddocks throughout the year. These are provided with tight shelters. African antelopes, Bovidae, live in heated quarters during the cold weather, but have access to outdoor enclosures during the warmer months. Natural pasturage is scanty or absent in all pens.

Prior to 1935, approximately half the diet of these ruminants was made up of mixed grains (equal parts by volume of cracked corn, crushed oats and wheat bran) and the remainder of mixed timothy and clover hay. Rock salt was the only mineral supplement. African antelopes received small amounts of fresh vegetables twice weekly.

TABLE II.

Records of Births and Deaths for Three Families of Artiodactyla (Bovidae, Cervidae and Camelidae) at the Philadelphia Zoological Garden During Each of Five Years Before and Five Years After the Diet Was Changed.

Year	*Stock*		*Acquisitions*	*Births*	*Deaths*	*Sales*
	♂	♀				
1930	70	48	1	20	14	6
1931	77	42	3	19	15	4
1932	74	48	2	17	24	2
1933	67	48	0	21	12	8
1934	59	57	15	16	24	10
1935	60	53	6	20	28	14
1936	53	44	12	14	18	9
1937	53	43	15	16	10	16
1938	54	47	0	18	13	24
1939	41	41	6	20	7	10

Neither the birth rate nor the death rate of these animals has changed materially since the present diet was offered. From 1930 to 1935, the average annual birth rate was 1 for 2.6 females and from 1935 to 1940, 1 for 2.3 females. The average annual death rate was approximately 15 per cent. throughout the period, but would have fallen to 12 per cent. after the change of diet, except for the sacrifice of 16 animals as excess or as unfit specimens.

From these observations it appears that the present diet offers little advantage, but the response of the ruminants is not well expressed by these data. Certain species of Cervidae and Bovidae seemed to be able to live and reproduce fairly well on the former diet. Examples of these are the Barbary sheep, *Ammotragus lervia,* Sika deer, *Sika nippon,* and possibly the Central American deer, *Odocoileus virginianus nemoralis.* On the other hand, American bison, *Bison bison,* elk, *Alces alces,* fallow deer, *Dama dama,* red deer, *Cervus elaphus,* Axis deer, *Axis axis,* and white-tailed deer, *Odocoileus*

leucurus, also reproduced but young matured slowly, rarely attaining the stature of wild-bred specimens. Many offspring of all species died shortly after birth, either because of lack of vigor or failure of the mother to lactate; and adult elk and white-tailed deer commonly developed progressive paralysis of the posterior etremities, due possibly to vitamin A deficiency.

The present diet seems adequate for maintenance of all species of Artiodactyla with which it has been tested. White-tailed deer have not developed paralysis of the posterior extremities during the five-year test period. Elk were not available for part of the time. Occasionally, new-born young, especially of hog deer, *Hyelaphus porcinus,* are lost shortly after birth, but in general, offspring mature normally. As one example, two generations of barking deer, *Muntiacus muntjak,* have bred while confined entirely within doors.

More recent studies of the nutritional requirements of domesticated ruminants, (Thurston, Eckles & Palmer, 1926), (Bechdel and co-workers, 1928), (McElroy & Gross, 1939), (Winegar, Pearson & Schmidt, 1940), indicate that the present diet for wild ruminants may be unnecessarily complex. Possibly it is, but the use of such a mixed ration seemed to be justified by the conditions under which the animals are exhibited, and by the fact that it is fed to non-ruminant herbivores such as the elephant, rhinoceros, hippopotamus, tapir, kangaroo and hyrax.

Carnivorous Animals.

Mammals and birds of this dietary group receive a ration which contains raw, ground horse-meat (approximately 20 per cent. glandular organs) 60 per cent., ground green vegetables, 10 per cent., and 30 per cent. of the following mixture:

Soybean oil meal	30 per cent.
Peanut oil meal	25 " "
Buttermilk (Dry)	25 " "
Oyster-shell flour	6 " "
Alfalfa leaf meal (Dehyd.)	4 " "
*Brewer's yeast (Dry)	4 " "
*Cod-liver oil concentrate	4 " "
*Iodized salt	2 " "

This is fed to animals of the families Canidae, Mustellidae, Viverridae, and Didelphiidae, and to birds of the orders Strigiformes and Accipitriformes. For these animals daily feeding allowances are 75 to 100 grams per kilogram of body weight, or 1 to 4 ounces per pound. It also forms part of the diet of other mammals and birds, but it has not been a successful diet for adult wild Felidae. On this diet, "husky dogs," foxes, wolves, skunks and opossums have bred successfully and offspring have matured without obvious defects. Judged by breeding, development of young and growth of fur, the ration seems to be adequate for these animals.

The hawks and owls, Accipitriformes and Strigiformes, have not had opportunity for breeding but the drop in mortality rate has been so pronounced as to warrant mention. From 1930 to 1935, the stock of Accipitriformes averaged 39.6 birds each year of which about 30 per cent. died. With almost the same average stock, 40.8 birds, from 1935 to 1940, the annual death rate has dropped to less than 10 per cent. The average number of Strigiformes exhibited from 1930 to 1935 was 19.8 birds of which 59 per cent. died each year. From 1935 to 1940 an average stock of 32.2 birds also lost less than 10 per cent. Prior to 1935 these birds had been fed only horse-meat. The chief causes of death were either non-specific inflammatory disease of the intestinal tract or simply failure of appetite. These conditions are no longer factors in mortality.

* See diet for omnivorous animals.

This diet for carnivores is one of many combinations that have been tested. Early in the work, 30 per cent. of the dry mixture for omnivores was used instead of the present dry material with the result that much of the grain-meals were undigested and stools were soft. This is in keeping with the observations of Hodson & Maynard (1938) on mink. In its essentials the present diet corresponds to the suggestions of Kellogg (1939).

On the whole this work has been an attempt to adapt available standards of nutrition to the needs of a zoological garden. The aim has been to provide acceptable, adequate and economical diets. Little training is necessary to induce the animals to take the foods, and costs of feeding have been reduced approximately 20 per cent. Whether or not the diets are completely adequate, in that continued breeding in captivity will be possible, remains to be determined. In all probability, the mixed rations that are being used could be further simplified without loss. The inclusion of iodized salt in all mixtures may be questioned, but its need seemed indicated by the frequent occurrence of hyperplasia of the thyroid in both mammals and birds that were examined prior to 1935.

It must be emphasized that a five-year test period is a relatively short time in which to evaluate reactions to these diets. This interval is only part of the normal life-span of all except the more short-lived specimens. The responses of the second and third generations must be awaited.

In planning the formulae efforts were directed to simplifying mixtures, using easily weighed amounts or standard bulk quantities as much as possible. Also, in actual practice food allowances are not arranged on a grams per kilogram of body weight per day basis. Instead, easily understood measures of the prepared foods are employed so that neither the keepers nor the workmen who prepare the foods are compelled to do more than follow a simple routine.

Summary.

A rather elastic classification of mammals and birds according to known food habits and the general structure of their alimentary tracts, permits the subdivision of the greater number of species that are exhibited in zoological gardens into three general groups. Three diets, the make-up of which was determined by the known requirements of related species, whether man or domesticated animal, by the preferences of the wild specimens, and by practical considerations, have been used for five years. Response to these diets, as judged by death rates, birth rates and development of young, indicate that advances in human and animal nutrition may be successfully applied to the feeding problems of zoological gardens.

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29.

The Biology of the Smoky Shrew (*Sorex fumeus fumeus* Miller)[1]

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(Plates I-IV; Text-figure 1).

The long-tailed shrews (*Sorex*) are cosmopolitan creatures, representatives of the genus occurring throughout most of North America, Europe and Asia. They reach their greatest numbers in temperate and sub-arctic lands, occupying a variety of habitats but seeming to prefer damp situations. Often these shrews are the most abundant mammalian representatives of extensive habitats, but their habits are little known. They have been religiously catalogued by the systematist, but as with most species, we know little more than their names, colors and measurements. This surprising dearth of information on such widespread and ubiquitous creatures is not surprising, for their diminutive size and retiring habits make them unworthy subjects for the attention of most naturalists. Nevertheless, these little mammals hold a peculiar fascination for some, for almost any planned study on these creatures will provide new information on their habits. The long-tailed shrews, if for no other reason than their very abundance, must play an important role in the habitat which they occupy.

The rate of growth, food habits, reproduction and behavior of *Sorex* has been little studied in North America. The best accounts, which are all too fragmentary, have been written by European students, the subject of their attentions being largely confined to the common shrew (*Sorex araneus*).

In 1927 I commenced a study of the small forest mammals of New York. Special efforts were made to secure life history data on the long-tailed shrews (*Sorex*). As time and opportunity have permitted, attention has been directed to solving the life history of the smoky shrew (*Sorex fumeus*). My repeated efforts to secure live gravid females, so that the young might be raised and described, have failed, but considerable data have been accumulated during the past ten years of study. Most of my studies have been made about Ithaca, in central western New York. The summers of 1937 and 1938 were spent on the Edmund Niles Huyck Preserve at Rensselaerville, Albany County, in eastern New York where large numbers of shrews were collected and population studies completed. Five hundred and sixteen shrews have been collected during the course of the study, and these have provided sufficient fresh material for rather complete studies on the various phases of the life of the smoky shrew.

Specimens were secured in small snap-back mouse traps baited with walnut meat, while a few shrews were captured alive in Sherman metal boxtraps.

[1] This study has been aided by a grant from the Elizabeth Thompson Science Fund of Harvard University which the writer gratefully acknowledges.

DESCRIPTION.

The smoky shrew is a relatively large *Sorex*, heavier and more powerfully built but with a shorter tail, than *Sorex dispar* which occupies part of its range. It is much larger than the common masked shrew, *Sorex cinereus cinereus*, which is occasionally found in the same runways.

The winter pelage differs decidely from that of the summer pelage. In winter the upperparts are deep mouse gray or slaty; the underparts are very much lighter, almost silvery. Some specimens have a buffy suffusion in the post-abdominal region. In summer pelage the upperparts are pale grizzled brown, the hair tips of the underpart being paler and gray at the base. The tail at all seasons is bicolored, straw yellow below and brown above. I have seen no albinistic specimens but old specimens occasionally have the hair tipped with white, or there may be a small patch of white fur on the thigh.

Summer specimens may be confused with *Sorex cinereus* (Townsend, 1935), but their greater size and darker color serve to distinguish them from their lesser kin.

Measurements. Three conventional measurements are made of mammals when they are caught and before they are made into scientific specimens, viz., total length (nose to end of last tail vertebrae); tail (base of tail to end of last tail vertebrae); hind foot (heel to end of longest claw). These measurements, unfortunately, vary with the collector and his methods, the condition of the specimen whether fresh, bloated, in rigor mortis, etc., and are largely a matter of personal equation. All the measurements listed below were made by myself, from freshly caught specimens taken in New York State.

Adult males. Twenty-six specimens average: total length, 116.5 mm.; tail, 41 mm.; hind foot, 13 mm.

Adult females. Twenty-two specimens average: total length, 116.3 mm.; tail, 43 mm.; hind foot, 12.6 mm.

Immature males. Seventeen specimens measure: total length, 113.5 mm.; tail, 41.4 mm.; hind foot, 12.7 mm.

Immature females. Fourteen individuals measure: total length, 113.1 mm.; tail, 41.2 mm.; hind foot, 12 mm.

Thus the measurements of 48 adults of both sexes average: total length, 116.4 mm.; tail, 41.9 mm.; hind foot, 12.8 mm. Thirty-one immature specimens average: total length, 112.8 mm.; tail, 41.3 mm.; hind foot 12.6 mm.

It is thus evident that the conventional external measurements provide little data on relative age, at least with this species. It is my belief that this is true of many small mammals. This belief is based on measurements of many hundreds of small mammals of various species in northeastern United States. Weights, external appearance (pelage, hairy tail tufts or bare tail tips, scarring of tail and feet) and above all, weight give a good index to the age of this shrew, and combined, are sufficient in themselves to give a ready clue to the approximate age of the animal. Tooth color and wear are infallible, and should always be resorted to in order to determine the age of the individual.

Weight. The smoky shrew has a variable weight, depending upon the amount of food it has recently ingested and also on its condition. Sufficient numbers, however, taken throughout the year, show a remarkable difference between the immature and mature animals, and the two may readily be separated on this factor alone.

Recently weaned shrews, about one month old, weigh 4 grams. They gain weight slowly and throughout the first 7 to 10 months of their lives weigh from 4 to 6.8 grams. Immature individuals of both sexes collected from June to November weigh from 5.5 grams to 6.8 grams, the average of 97 specimens of both sexes being 6.19 grams. There is no sexual variation in the weight of immature shrews.

During March, the shrew population (those which have been born the previous year) gain weight rapidly and continue to become heavier throughout the spring and summer until they die. Twenty-nine adult males collected from March to August average 8.94 grams, the extremes ranging from 6.4 grams to 11 grams. Twenty-four females collected during the same period average 7.44 grams, the extremes for these, with embryos removed in gravid individuals, being 6.7 grams to 10 grams. It is very unusual to take these adult shrews after August, and it will be shown later that they die of old age at this season.

Molt. It has already been shown that the summer pelage varies markedly from that of the winter, but the change by no means occurs at the same time each year, and it may occupy several months in any one region.

Jackson (1928) states that in the southern part of the range of *Sorex fumeus* the spring molt may begin as early as the middle of April, though most specimens at that time are still in full winter pelage. He records individuals showing molt from April 19 in the south to July 18 in the north. Jackson observed that the fall molt occupies the period during October and November, depending in part upon the latitude.

In New York it is usual to find these shrews in full winter pelage from late September until early May, although the majority of museum specimens are in summer pelage. This merely indicates that collectors are most active during the summer months. The progress of the molt is a rather insidious affair, sometimes well marked and again the hairs being shed generally over the entire body so that little demarcation can be seen between the gray pelage of winter and the brown hairs of summer. The earliest record of molt is seen in an April 22 specimen, which has a large patch of summer fur on the belly and chin.

Usually by mid-May the summer pelage has been obtained, although it may be long delayed. An adult male taken on May 6, 1938 has a few hairs of the winter pelage remaining irregularly over the back, the inguinal region and particularly the rump. On June 21, 1936, I collected an adult female which had attained the complete summer pelage except for a small patch of winter fur about the base of the tail.

The summer pelage is retained until late September or early October. Three immature shrews collected in the last week of September, 1935 and 1936, have a few patches of summer fur, usually about the head and base of the tail. Fifty-seven immature shrews collected from September 27 to October 9 were all in winter pelage except one, which had a few hairs of the summer pelage about the ears. Males tend to molt earlier in the spring and fall than females. Breeding is well under way and the first litter produced before the females have completely shed their winter coat. This is contrary to the findings of Green (1930) who trapped a gravid female on April 18, 1928, at Ricketts, Pennsylvania, in which the molt was beginning on the abdomen.

A smoky shrew is seldom collected which shows any sharp demarcation between the winter and summer pelage. The molt appears to commence on the belly, and extends over the shoulders and middle of the back, the old fur persisting longest about the ears and rump.

Inasmuch as shrews in any given locality exhibit all stages of molt over a rather long period, particularly during the spring, it might be assumed that the change of fur in the individual occupies several weeks. Wilcke (1938) observed that a captive *Sorex araneus* shed its long gray shaggy winter coat during the first two days of captivity, assuming the dark shiny summer coat in rapid time.

On May 6, 1938, I collected a large male at Ithaca, New York, which showed a prominent molt over the back and rump. Long winter hairs stood out irregularly from the new short brown fur of summer. During the two days this animal remained alive, all the winter fur was lost.

Habitat.

The smoky shrew is a northern species, reaching its abundance in the cool forested regions of Pennsylvania, New York and New England. In the beech-hemlock-striped maple woods with a ground cover of loose leaf mold and black friable soil, it is often found in considerable numbers, and, unlike its congener, *Sorex cinereus,* appears to be largely restricted to such a habitat. In New York it is often abundant in birch-hemlock woods, but is only poorly represented in the thin-soiled, rocky, dry, maple woods. While the shrew perhaps favors damp woods, and the vicinity of streams, it is often taken in areas far removed from water. This species seems particularly fond of the moss-covered boulders which lie along the wooded south slopes of valleys, where the sun does not penetrate far in the summer.

In the deep leaf mold of northern forests, one can often push a finger through the surface layer to find a cavernous void beneath the inch or two of soil which covers so completely the world beneath. By tearing away this superficial layer, the tortuous galleries and broad runways of many small forest mammals are exposed. It is in this retreat, made by the larger *Blarina,* red-backed mice, hairy-tailed moles, and kindred forms, that the smaller *Sorex* are often found in profusion, a highway of mammal travel scarcely visualized by the inexperienced observer. During the hot days of August, 1938, I made several records of temperature in these retreats. In the open woods and the borders, my thermometer read 89° F. Within the woods, where little direct sun penetrated, the temperature was 81° F. In the covered galleries of the small mammals, 6 to 10 inches below the level of the forest floor, the temperature read 69° F. Conversely, in the winter, when the forest floor was free of snow, the galleries of these animals, hidden below the forest litter, had a temperature ranging from 20° F. to 31° F. while the exposed forest floor had a temperature of 8° F.

The clumps of yew (*Taxus canadensis*) which grow from the deep leaf mold are favorite retreats for these small shrews and many have been captured in such places. The runways of moles, the tunnels canopied by rotting logs and the leaf-filled depressions which obscure so well the labyrinth of tunnels, all yield their *Sorex.*

The smoky shrew population is by no means evenly distributed throughout the forest. While there is no evidence of a communal or gregarious nature, they prefer certain localities to others and here they may often be found in some numbers. A typical habitat is shown in Plate I, Fig. 1.

Activity.

In general, shrews are active at all hours, trapping records to date not indicating that these animals have any particular time in which to feed or move about. The three common shrews of eastern United States, *Blarina brevicauda, Sorex fumeus* and *S. cinereus,* are active at all hours of the day and night. It appears possible that the presence or absence of suitable cover may limit their movements to certain periods, but my trapping records do not indicate this. By far the greater number have been taken at night, but this is accounted for by the collecting methods employed. In the course of the investigation, traps have been generally set in the afternoon and not attended until the following morning, so that no positive record has been obtained for the majority of specimens collected.

In order to determine at what hour catches were made, large numbers of traps were set at various times of the year and visited at 6-hour intervals. The results appear in Table I.

TABLE I.

Activity of *Sorex fumeus* as determined by time of catch.

	6 AM-12M.	12M-6 PM.	6 PM-12M.	12M-6 AM.
June 12-14, 1932 150 traps set 5-6:30 AM June 12	2	4	3	2
April 14-15, 1939 130 traps set 1-2:30 PM April 14	3	2	5	3
June 24-27, 1937 200 traps set 6 PM June 24	5	3	8	6
Oct. 6-7, 1938 140 traps set 3 PM Oct. 3	3	5	1	5

From the table above it can be seen that 27 shrews were taken from 6 A.M. to 6 P.M. while 33 shrews were trapped from 6 P.M. to 6 A.M. Although the number is admittedly small, it shows that these shrews are active at all hours. Inasmuch as these shrews live in the deep leaf mold and forest litter, they are not particularly susceptible to predation at any particular time. Their diminutive eyes probably hardly distinguish light from darkness.

ASSOCIATES.

The forest floor which serves these little shrews, provides a home for many other species. Within the same habitat many other small mammals are to be found, perhaps competing with these mammal sprites for nest sites and food. These associates vary in their numbers both from year to year and in the various habitats which one selects to study. The relative population of these to other small species may best be illustrated by noting all mammals taken on a trap line over a unit of time in similar habitat. The following examples will serve.

Maple-beech-hemlock woods, good leaf mold. Ithaca New York, June 28-29, 1939. Three hundred trap nights. *Sorex fumeus*, 9; *Blarina brevicauda*, 27; *Napaeozapus insignis*, 10; *Peromyscus leucopus noveboracensis*, 9. *Sorex fumeus* represents 16.4% of catch.

Beech-hemlock woods with deep leaf mold. Rensselaerville, New York. August 6-14. 1938. Seven hundred and fifty trap nights. *Sorex fumeus*, 18; *Blarina brevicauda*, 60; *Peromyscus* (principally *P. leucopus noveboracensis*), 66; *Synaptomys cooperi*, 6; *Zapus hudsonius*, 2; *Microtus pennsylvanicus*, 1. *Sorex fumeus* represents 11.8% of the catch.

Beech-hemlock woods with deep leaf mold. Ithaca, New York. Oct. 4-7, 1939. 800 trap nights. *Sorex fumeus*, 27; *Blarina brevicauda*, 24; *Peromyscus leucopus noveboracensis*, 26; *Clethrionomys gapperi*, 7; *Pitymys pinetorum scalopsoides*, 2; *Microtus pennsylvanicus*, 2; *Parascalops*, 1. *Sorex fumeus* represents 20.2% of the catch.

In the records above, it is seen that *Sorex fumeus* comprises 11.8 to 20.2% of the small mammal population in ideal shrew habitat for certain regions in New York. If these totals be averaged, it is found that, in the three areas discussed, *Sorex fumeus* comprises 18.3% of the small mammal population. In the northern part of the state, as the Adirondack region, and much of northern New England, certain species become more abundant, such as *Clethrionomys* and *Sorex cinereus*, and the *fumeus* population in these regions would comprise a smaller percentage of the catch.

Burrows and Nests.

The weak feet of these small shrews make digging a difficult procedure and as a consequence they utilize and occupy burrows made by larger mammals. Deep in the leaf mold are prominent subterranean galleries, some the diameter of a baseball, and others whose bore scarcely exceeds the diameter of a penny. In these burrows, from an inch to nearly a foot below the leaves and humus ceiling, a host of small mammals move, feed, breed and die. These burrows are made chiefly by the powerful hairy-tailed mole, the short-tailed shrews and certain small rodents, notably the red-back mice, jumping mice and lemming mice. Chipmunks often tunnel for some distance below the soil, and the loose texture of the rotting logs and stumps make progress easy beneath these decaying objects. The tiny *Sorex* utilize these burrows, and are often caught in such places. They occasionally occupy the punky moss-covered logs which lie half hidden in the trash and rotted leaf mold of the forest.

As evidence that little burrowing is done by these diminutive creatures, I placed smoky shrews in sizeable aquaria partly filled with friable loam pressed to a consistency found in the normal habitat of these animals. Little effort was made to dig, and when the animals did try to displace dirt with their fore paws, the efforts were weak and ineffective. It seems probable that they make no burrows but utilize entirely the runways of other species.

The nests are placed at various places in these tunnels, a favorite site being beneath a stump or rotten log. I have found one nest composed almost entirely of the hair of a cottontail rabbit, situated beneath a stump from which a shrew ran when the nest was exposed. Other nests which I have examined have been made of shredded leaves, usually situated from 4 to 9 inches below the surface. These nests are roughly spherical in shape and approximate a baseball in size. They are more compact and somewhat smaller than the bulkier nests of *Blarina*. One nest which I presume had been made by a smoky shrew (a specimen was trapped in a runway leading from the nest) was situated in a punky log which crumbled apart easily. The nest was placed at one end of the log near its base and communicated with several burrows leading into the soil beneath. Another was found at the bottom of a large mass of rotten logs which had been piled by a woodcutter, and allowed to disintegrate. This nest was placed directly on the ground, between two logs which formed part of the foundation of the pile.

None of the nests contained remains of food, but piles of scats were usually found within a few inches of the nest. Captive shrews are certainly sanitary creatures, often reserving a corner of the aquaria farthest removed from the nest in which to deposit their feces. All the nests which I have examined have been free of parasites.

Voice.

The long-tailed shrews utter diverse little notes, all with probably some meaning. When alarmed, or approached by a larger mouse or shrew, the smoky shrew utters a high pitched grating note, not unlike that of the smaller bats. If greatly disturbed, it will throw itself on its back, and with spread and waving legs, repeatedly utter these squeaking staccato notes. When foraging for food these little shrews utter an almost indiscernible twitter. I have twice seen these little forest mammals rooting through the leaf mold or appearing on the forest litter about rotted logs, the twitching nose and vibrissae held aloft, and this faint, almost inaudible twittering was kept up continually.

Senses.

In spite of the diminutive eye (Plate I, Fig. 2) sight appears to be of some importance. In very subdued light where captives were housed, the shrews experienced little difficulty in avoiding obstacles and actually turned from their trails to explore new objects which were placed in the pens while the animals were exercising. In the thick carpet of leaves and the dark tunnels beneath the forest litter, there is little need of good eyesight and it is probable that these organs are degenerating.

The sense of smell does not appear to be particularly well developed. Little opportunity was had to test this sense, but when odorous food was placed in the boxes of hungry shrews, the animals often appeared to experience difficulty in locating the food items. Indeed, on several occasions they came within a few inches of small pieces of liverwurst, which were shallowly buried, but did not find the food until they had hunted for some time.

Hearing is reasonably acute. Gentle squeaking will alarm the shrews, while loud and prolonged clapping of the hands will cause the shrews no disturbance. Blossom (1932) refers to the apparent immunity of *Sorex cinereus* to loud sounds. Sleep is often so sound that snapping the fingers or loud whistling fails to disturb the shrews immediately.

The tactile sense appears to be well developed, and the long facial vibrissae may well enable the shrew to intercept disturbances which the other senses fail to detect. Indeed, there is some reason to believe this, else why do these little creatures forever hold their long cartilaginous snouts in the air, the mobile tip and associated vibrissae moving so rapidly that it is all the observer can manage to follow these extraordinarily rapid motions?

Food.

The smoky shrew is admirably adapted for gleaning the forest floor. Its long snout, with stout inner cartilaginous support, enables it to push through the leaf mold and loose litter, and its strong hooked and protruding incisors act as efficient tweezers to gather the minute life which swarms in this habitat. Elsewhere (Hamilton, 1930) I have reported on the stomach contents of 31 *S. fumeus* which were taken from February to December. All of these contained insect remains, these being, in the order of their abundance, undetermined larvae, Coleoptera, Diptera and Hymenoptera. In addition, centipedes, sowbugs, earthworms, salamanders and vegetable matter were found.

I now have the analyses of 168 stomachs to report. These were taken in New York during every month, but the greater majority were secured in the spring and the fall. Specimens taken while a deep layer of snow covered the ground contained fragmentary remains of insects, principally small golden pupal cases and fragments of beetles which were presumably dormant. One contained what appeared to be the meat and skin of a beechnut. A dozen shrews secured in March while the ground was well frozen contained quantities of insect fragments, including dipterous remains and the legs of centipedes. During May the shrews feed chiefly upon insects, particularly beetles and their larvae, and eat a few spiders. One shrew had the toes and flesh of a small salamander, while another had parts of a snail, probably *Polygyra*. Still another had eaten several small feathers, possibly secured from a dead bird, for it is improbable that these delicate little mammals could successfully overcome a sleeping bird, even though it also be of diminutive size. I have seen juncos sleeping among the *Taxus* clumps when examining my shrew traps at night.

During the summer months the principal food of the shrews appears to be insects, but the stomachs of at least two taken during July contained a mass of flesh and fur. Again it seems improbable that the animal was not a victim of the shrew, but rather met its death in some other manner. None of the trap victims had been touched, however, upon the occasion when these two were taken. Snails, small earthworms and a quantity of vegetable matter have been recognized in autumn specimens but the food appears to differ little from that of the summer.

TABLE II.

Food habits of *Sorex fumeus,* determined from examination of 168 stomach analyses made throughout the year. The figure below the month indicates the number examined. Other figures denote the percentage frequency of occurence of the different food items.

Food	Jan. 4	Feb. 5	Mar. 14	Apr. 27	May 20	June 16	July 19	Aug. 8	Sept. 17	Oct. 21	Nov. 11	Dec. 6	Total 168
Insects	75	80	85.7	77.7	70	93.7	94.7	100.	88.2	52.4	81.8	66.6	80.0
Earthworms	..	..	7.1	14.4	15	6.2	10.5	12.5	...	9.5	23.3	...	10.1
Vegetable	50	20	14.1	14.4	25.0	18.7	5.3	50	...	...	18.2	50	14.9
Centipedes	25	..	21.4	18.5	5.0	18.7	15.8	...	5.9	9.5	18.2	16.6	13.1
Snails	..	20	...	11.1	10.0	...	10.5	...	17.6	23.8	9.1	...	10.1
Salamanders	..	..	...	3.7	5.0	...	5.3	...	...	...	...	...	1.8
Mammals	..	..	...	3.7	10.0	...	10.5	...	...	...	...	...	3.0
Sowbugs	..	..	...	11.1	...	6.2	21.1	...	...	...	9.1	...	5.3
Spiders	..	20	...	14.4	10.0	6.2	...	12.5	...	...	9.1	...	5.9
Birds	..	..	...	...	5.0	...	...	...	...	...	...	...	.6

Food Requirements. On several occasions I have had captive smoky shrews for variable periods and have observed their feeding activities. These shrews are not the prodigious feeders that many naturalists would have us believe; they never eat food equivalent to their own weight daily, at least in captivity. Nevertheless, Dixon (1924) has demonstrated that the little gray shrew (*Notiosorex*) will eat 75% of its own weight each day. Blossom (1932) observed that a captive female *Sorex cinereus,* weighing 3.6 grams, ate an average daily weight of 11.7 grams, that is, an average of approximately 3.3 times its own weight every twenty-four hours. Wahlstrom (1928) states that the food requirements of *Sorex vulgaris* are enormous and the ability to fast, even when the animal is in good health, is very low. On the other hand, Rorig (1905) maintained that a small amount of food was quite enough to maintain a captive *Sorex araneus* in good health. The shrew ate an average of 7 grams of mealworms, grubs and flesh, and was maintained for nearly three months. Inasmuch as an adult shrew of this species weighs about 12 grams, it may be seen that slightly more than half of its weight in food each day is sufficient to keep the animal in good health.

It may be that conditions under which captive shrews are kept determine their ability to survive on a moderate amount of food. Moreover, a varied assortment of *natural* foods appear to keep the captives more contented than a restricted diet of mealworms or cockroaches. My captive shrews had an assortment of small snails, mouse flesh, small earthworms, beetles, centipedes, sowbugs and siftings from the forest floor, including many spiders. All seemed to do well on this variable diet, and maintained themselves many days on an amount not exceeding half of their weight. Still, this quantity is an incredible amount for such a diminutive animal to consume. Much of the food is bulky and indigestible, for the chitinous remains of the prey pass with the feces in a state which frequently makes identification of the parts quite possible. The shrews eat at all hours, the only stay to their hunger being the necessity for short naps and the actual search for food, which seldom appears to entail any great labor.

Feeding Habits in Captivity. The most important sense utilized in searching for food appears to be that of touch. While hearing is rather acute, sight and smell seem to play a minor role, and the ever moving snout and long vibrissae probably are of major importance in apprising these shrews of their food. They utilize the burrows of many small forest rodents and the larger shrews, and within the confines of these tunnels the small prey has little chance to avoid capture. Moreover, the leaf mold may be riddled with their temporary tunnels and it is suspected, from the actions of captive specimens, that much of their prey is secured by the sensitive nose. Small prey, like flies, tiny isopods and centipedes, soil worms and the lesser beetles are merely bitten and swallowed. The larger food items, as earthworms, snails, salamanders or newborn mice are held down with the fore feet while pieces are bitten off. Wireworms, mealworms, the larger beetles and kindred prey are first paralyzed by being bitten in the head. Small salamanders (*Plethodon cinereus*) are held firmly to the ground and quickly destroyed by being bitten in the head or back, severing the spinal cord. The feet, head and viscera of these amphibians are first eaten, the remainder often being neglected for other food.

It appears improbable that these small shrews are capable of overcoming deer mice and the other small rodents which inhabit their domain. A small *Peromyscus*, weighing 14 grams, was liberated in a large aquarium with an adult *fumeus* weighing 10 grams. The shrew made several abortive efforts to capture the mouse, and once closed in, grasping its active prey by the flank. The mouse immediately broke this hold, and the discouraged shrew thereafter paid no heed to its intended victim.

Sorex fumeus probably obtains sufficient water from its food, for captives drink only a limited quantity, dipping the snout into the pan of water and tilting back the head like a chick. Blossom (1932) gave no water to his captive *S. cinereus* over nearly a three month period. Wahlstrom (1928) found his captive *Sorex vulgaris* never drank; indeed they seemed to fear the water, and one shrew upon falling into its drinking receptacle avoided it thereafter. On the contrary, captive specimens of *Sorex araneus* observed by Wilcke (1938) drank very freely, in fact after every meal.

Reproduction.

Male Reproductive Organs. The following description is based on the genital organs of a sexually mature male (Plate II, Fig. 3). The testes are oval and measure 4 by 8 mm. but occasionally are larger. The caput epididymis is often diffused and ill defined and usually partly embedded in a mass of yellow fatty tissue. The cauda epididymis is large, and in breeding animals the convoluted tubules may be distinctly seen with the aid of a low powered binocular microscope. If the tubules are visible through the walls of the epidydimis, they invariably contain sperm. This serves to determine whether the males are in a breeding condition. The proximal end of the vas deferens commences as a narrow tube, gradually swelling until its distal two-thirds is reached. Here a prominent constriction occurs, the distal part being enormously swollen into a pouch which gradually tapers until its junction with the urethra is reached. The distal swelling has a diameter 4 or 5 times as great as the tubal portion of the vas deferens. A similar condition prevails with *Blarina*, but is never so well marked. According to Brambell (1935) these swellings are composed of alveolar pouches which store sperm. During the spring, one can slit the distal pouches and make a smear which usually contains numerous sperm. Two large paired organs, with numerous villi, somewhat larger than the testes, and lying dorsad to the vasa deferentia and the bladder, have been designated the prostate glands by Arnbäck-Christie-Linde (1907). These nevertheless appear to be the seminal vesicles, for they appear essentially the

same as these latter structures in other small mammals. Their true homologies cannot be determined until a careful developmental study is made of these and associated structures in several insectivores. The large bean-shaped Cowper's glands, about two-thirds the size of the testes, lie at the base of the tail, and dorsally give one the impression of anal glands. The penis is a large organ for so small an animal. When retracted it is folded on itself so that the tip lies over the most proximal portion. When extended, it measures 16 to 18 mm. There is a suggestion of diffuse prepucial glands but no ducts are visible. The penis is without a baculum.

Weber (1898) implies that the testes in the Soricidae leave the pelvic cavity seasonally or voluntarily. I have never found the testes situated other than in a cremaster sac outside the pelvic cavity and lying near the dorsal tip of the pubis. Even in very young shrews, the testes may be teased into view with the forceps by grasping the sac and drawing the testes out. In immature shrews, the caput epididymis is more prominent than the testis, both in size and in the lighter color. Apparently the enlargement occurs within the sac, without change of position of the testes during their enlargement.

The increase in size of the reproductive organs at the onset of the breeding season must occur with great rapidity. Specimens secured in March have either very minute testes whose associated structures are barely visible macroscopically, or else the organs are much enlarged. From extensive field observation and dissection of more than a hundred males taken in the late winter or early spring, I should judge that the enlargement of the testes, seminal vesicles and Cowper's glands does not occupy more than 3 or 4 days.

The Female Reproductive Organs. The female reproductive organs of *Sorex araneus* have been well described by Brambell (1935). These organs in *Sorex fumeus* (Plate II, Fig. 4) do not differ markedly from the former species. Inasmuch as these organs are often of minute size, and their parts not easily determined, it seems desirable to give a brief description of them so that American investigators may recognize the different structures.

The ovaries of immature and anoestrous adults are minute, oval yellowish bodies, measuring no more than 1 mm. in length. The much larger ovaries of breeding animals appear like small mulberries, with corpora lutea and follicles projecting above the surface. The corpora lutea, numbering 2 to 5 for each ovary, often occupy the entire ovary. A prominent periovarian sac completely invests the ovary. The oviduct is well marked from the uterine cornu, its ovarian part having a much greater diameter than the uterine end. The entire oviduct is bent in the form of an S. Brambell (1935) states that the Fallopian tube passes diagonally through the uterine wall and projects slightly into the uterine lumen. When stretched taut, the uterine horns join at right angles to the elongated vagina, but when in situ they are coiled and thus occupy little space. The vagina is unique in being bent back upon itself, the distal portion lying dorsad to the proximal portion, so that the junction of the vagina with the uterine horns lies near the site of the bladder. This is an adaption for the excessive length of the vagina which, if it lay in position similar to other small mammals, would reach nearly to the kidneys. The lower part of the vagina merges into the urogenital sinus, where the urethra opens. The clitoris is not well marked.

The three pairs of teats are inguinal, their glands occupying much of the post abdominal and inguinal region in lactating individuals. The first pair of glands are by far the largest, occupying a large area in front of the thighs and extending almost to the sacral vertebrae. In immature shrews and anoestrous females they are small and inconspicuous.

The Breeding Season. The season of reproduction normally extends from early April into August.

Males. Males secured in January and February are all immature, weighing from 4.2 to 6 grams. The testes of these animals are minute and contain no sperm. In order to determine what individuals were fecund, the testes were removed, freed from all extraneous tissue and weighed. Microscopic examination of the epididymis was made to determine the presence or absence of sperm. It was soon evident that size of testes and macroscopic examinations of the epididymis were sufficient to determine fecundity. When the combined weight of the testes exceeded 75 milligrams, they invariably contained mature and abundant sperm. Those individuals which were not fecund had small testes, seldom exceeding 2 mm. and together not exceeding 10-15 milligrams. Sexually mature individuals possessed testes measuring 4 × 6 mm. to 4.5 × 8 mm. and the pair weighed from 105 to 145 milligrams.

The change in size of the testes and the increase in weight of the shrew at the commencement of the breeding season is accomplished with great rapidity. Several specimens taken in mid-March of successive years weigh only 5 or 6 grams and have minute testes. During the last week of March a number have been secured weighing 8-11 grams and containing enlarged descended testes which have numerous sperm. On the same dates a few have been collected which still retain their small obscure testes and give no indication that they will, in a few days, become fecund. I have taken no immature shrews from early April until early June. All males secured during this period have had enlarged testes, with swollen vas deferens and seminal vesicules (Plate II, Fig. 3). Adult males continue to maintain their fecundity through August, and the only adult captured in early September likewise had enlarged testes and abundant sperm.

Females. The females, like the males, are all immature during January and February, and show little sexual activity during March. Four females collected on March 29 weigh 6.7—10 grams, and all but one show no sign of breeding. This individual has a swollen uterus and indicates sexual activity, but there are no corpora lutea nor any sperm in the vagina. Nine females collected from April 12-14 are, judged by weight, mature animals but none were pregnant. Shrews taken on April 22 contain embryos measuring from 1-7 mm. Individuals taken on May 1 contain embryos but are not nursing. On May 5 I took 2 females, one of which contained five 5 mm. embryos and another which was actively nursing. The uterine horns show only faint placental scars, so parturition probably occurred prior to May 1.

Mating may follow partus as it does with numerous cricetine rodents, for a large female taken on May 16 was actively nursing and contained eight 2 mm. embryos. Two other females taken on the same date were nursing but were not gravid. In late May a number of lactating females have been examined, but none of these were pregnant. Twenty-four adult females taken during June were all in breeding condition. Of these, 4 were pregnant and the remainder were nursing individuals. Thirteen adult July females were all nursing, and 2 were pregnant. During August, adult shrews become increasingly scarce, only one of the 4 adult females which were examined during the second week of this month being in a breeding condition. No breeding occurs during September. An interesting instance of October breeding is given by Green (1930) who took a recently nursing shrew on October 11 at Ricketts, Pa. This is a most unusual circumstance and is difficult to explain, inasmuch as I have examined 68 females during this month, and all have been immature animals.*

From these data it may be seen that males become fecund earlier in the spring than the females, and individuals usually continue in a breeding condition after the females have all died or at least ceased to breed. It is thus concluded that the female controls the breeding season, a condition

* Of 32 females taken at Ithaca, N. Y., from Oct. 3-10, 1940, one was a recently lactating adult.

similar to that of *Blarina, Peromyscus* and several other small mammals which I have studied.

Duration of Pregnancy. Little data are at hand regarding the gestation length of shrews. This is, in large measure, due to the difficulty of keeping these animals in captivity a sufficient time to breed and thus observe the gestation period. *Blarina* has a probable gestation period of 21 days (Hamilton, 1929). According to Brambell (1935), the probable gestation of *Sorex araneus* is between 13 and 19 days, with a similar lactation period.

If sufficient numbers of adult females are examined prior to the inception of the breeding season, and suitable samples obtained at several day intervals, it is possible to estimate the probable length of the gestation. Prior to April 15, no pregnant shrews have been secured, although more than 20 individuals have been examined from March 15 to April 15. On the latter date, vaginal smears from one individual indicated the shrew was in oestrous. On April 22 and 23, shrews which I examined contained embryos having a crown-rump measurement from 1 to 7 mm. On April 26, 29 and 30 and on May 1, several shrews contained embryos measuring from 3 to 10 mm. The earliest records of lactating shrews occur on May 5, when 2 nursing specimens were secured. One had faint placental scars while the other had produced young very recently. Females taken on May 3, 5 and 9 were all actively lactating.

If the earliest pregnancies occur on or about April 15 (based on the 7 mm. embryos secured on April 23) and the earliest parturition date on or about May 4, this would place the gestation length at approximately 3 weeks. It appears likely that the gestation of this shrew is no longer than 3 weeks duration, and probably somewhat shorter.

Litter Size. Based on counts of embryos and placental scars in 42 females, the litter size averages 5.5 embryos per female. Absorption of the embryos occasionally occurs, particularly in the late litters so that an embryo count is not a positive criterion of the young actually produced. Nevertheless, the six mammae suggest that 5 or 6 young are the usual number born (Plate III, Fig. 5). The largest embryo count was 8, the smallest 2. Middleton (1931) has shown that the litter size of *Sorex araneus* becomes smaller in July, at the close of the breeding season. One might suppose that as the females became senile and approached death during mid- to late summer those continuing to breed would have smaller litters. Such diminution is not well marked. In April the litter size, based on embryo counts, was 5.8. During May it averaged 6.2; for June, 5.5, and for July, 4. A July 12 female contained 2 embryos. The single pregnant August female contained 6 embryos, one of which was being resorbed, while a lactating shrew taken on August 12 had 4 placental scars.

Dermal Glands.

Side Glands. All soricids possess side glands, small oval areas of agglutinized hairs on the side of the body midway between the fore and hind limbs. These glandular areas are composed of enlarged sweat glands lying in the deeper part of the corium of the skin and of large sebaceous glands above the sweat glands in the upper portion of the corium (Eadie, 1938).

Arnbäck-Christie-Linde (1907) found side glands restricted to the male in *Sorex vulgaris* and *Crossopus fodiens* but present in both sexes in *Crocidura.* Both sexes of *Sorex fumeus* possess these glands, although they are better developed in the male than in the female. The glands may not be evident in immature females, whereas in immature males the glandular areas are always marked on the flesh side of the skin.

A noticeable enlargement of the side glands occurs in the late winter,

coincident with the enlargement of the reproductive organs. The glands then become highly vascularized (Plate III, Fig. 6) and are evident as large reddish patches on the skin surface. Johnsen (1914) believes the scent glands, at least in the male, play an important part in the sex life of the animal. He has observed that in male shrews, the growth of the sweat glands and preparation of the secretory stages parallel the ripening of the testes. This condition certainly obtains for *Sorex fumeus*. Throughout the breeding season, the glands remain prominent in both sexes, although non-breeding adult females do not exhibit pronounced glands.

The function of these glands is problematical, but it seems possible they act in some manner to attract the sexes during the breeding season. Their relation to reproduction is evident, for only at this season are the glands well developed.

On June 12, 1932, I captured a female smoky shrew in a tin trap. The animal had been dead a short time. As I was standing near the trap, a shrew appeared in the runway, ran about the trap several times and appeared to be much excited. Its side glands were very evident, the hairs about these structures being laid back so that the semi-glabrous glandular area could readily be seen. No odor was visible until I knelt down and smelt closely of the burrow it had occupied, when the peculiar and characteristic smell of this shrew was quite evident.

Life Span.

It has long been apparent that the long-tailed shrews caught at periods other than the spring and summer months (late March to early September) were all immature individuals. A critical examination of these specimens suggests that the smoky shrew does not become mature until late winter and almost the entire adult shrew population dies during the late summer.

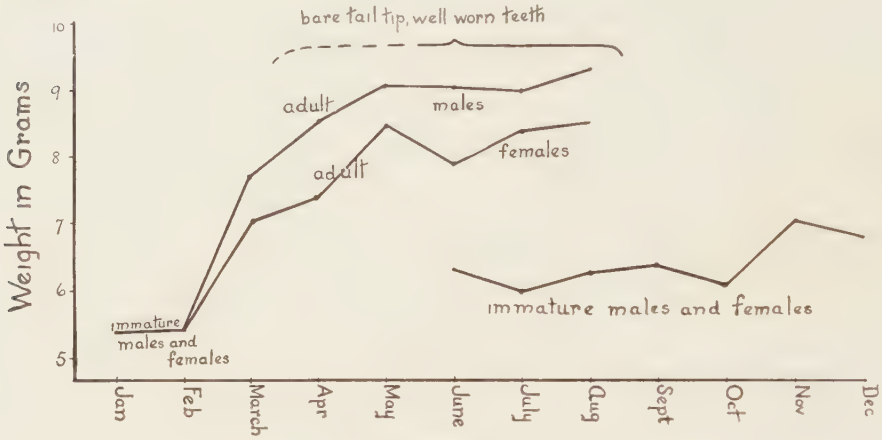
Many observers have remarked on the supposed autumnal mortality of *Sorex*, but Adams (1910) was the first to suggest the true cause. He could trap no adult males nor females after December, and concluded that the autumnal epidemic is due to nothing other than old age, this being reached in the case of *Sorex araneus* and *S. minutus* in thirteen or fourteen months. Middleton (1931), apparently unaware of Adams' study, reached a similar conclusion, viz., that all adult shrews (*Sorex araneus*), following the short but prolific breeding season, gradually die out, so that none are left by the following winter. Recently Brambell (1935), from a study of 1,064 trapped shrews (*Sorex araneus*), likewise concludes that the females live over a single winter only and die at the close of their first breeding season, the year following that in which they were born, and that the young males do not breed in the season in which they were born, and do not live over a second winter.

Montague (1922) questions the abundant testimony in support of this short life span, for a specimen of *Sorex araneus grantii* which he collected in June appeared to be undoubtedly above normal age, the teeth being almost completely worn away, while the coat is grizzled.

Certain distinguishing characters readily separate the immatures from the adults of *Sorex fumeus*. Shrews weighing 7 grams or more may be considered adult. Those with glabrous tails, the tip more or less rounded and blunt, with few or no hairs and often with numerous scars, may be considered adult. Prominent tooth wear is characteristic of adult shrews (Plate IV, Fig. 8).

Perhaps the most distinctive feature of young shrews is the general hairy condition of the tail, particularly at its tip. In young shrews, this member retains its hairy condition until April, when the shrews are eight to eleven months old (Plate III, Fig. 7).

During the year in which they are born, none of these young shrews become sexually mature. I have carefully examined the reproductive organs of more than 300 fresh immature specimens, and all indicate a quiescent stage, in which the testes are minute, seldom exceeding a millimeter in length, and the ovaries microscopically showing no indication of sexual activity. Moreover, I have collected only one adult shrew later than the first of October. It is probable that a few adult females live into the fall, for Green (1930) secured a nursing *Sorex fumeus* in northern Pennsylvania on October 11, 1927. Brambell (1935) states that immature females of *Sorex araneus* may exhibit signs of precocious sexual activity in the autumn of the season in which they are born. Even though follicular growth and vaginal cornification occur there is no evidence that these immature shrews become functionally mature. Such animals gradually pass into the typical winter condition.



Text-figure 1.

Graph demonstrating the relation of weight to age. A pronounced acceleration in weight is evident in March, when both sexes, which have overwintered as immature individuals, become sexually mature. From April to September, adults may be recognized by the increasingly worn condition of the teeth and the glabrous condition of the tail. The pencil of hairs is usually lost in May or June, but a few may be retained into August. It may be seen that the adult shrew population dies during August. A few may survive into the fall, but such is most unusual. The immature shrews lose weight in mid-winter, but their transition in March from immaturity to adults is remarkably rapid.

Examination of Text-figure 1 will show the marked disparity between the weights and tail condition of immature and adult shrews. We may thus conclude that, with *Sorex fumeus*, all of the adults, after completing their reproductive duties, die of old age when they are fourteen to seventeen months old.

Populations.

Our small native mammals are, for the most part, cyclic in nature, their populations varying from year to year. Some seasons they may exist in considerable numbers, while in other years only a few may be trapped.

During July and August, 1938, I trapped various habitats on the Huyck Preserve at Rensselaerville, Albany County, New York, to determine population levels of small mammals. In the more favorable habitats of beech and hemlock, with ground cover of *Taxus* and broad leaved herbaceous species, deep leaf mold and litter, I established several quadrats measuring

100 by 100 feet (.23 acre). Within these areas 300 traps were placed in the most promising runways, particularly in subterranean burrows and trails beneath the leaf mold. These traps were visited at dusk and dawn for a three-day period, or until the catch had been so reduced it was assumed the major part of the population had been removed. On one of these quadrats 65 small mammals were taken in three nights, 12 of which were *Sorex fumeus*. On another plot in similar habitat a quadrat yielded 68 small mammals, 10 of them being *Sorex fumeus*. In an open, sparsely wooded second growth stand of beech, maple and hemlock, with thick carpet of leaves and moss, 41 small mammals were collected on a quadrat. Six of these were smoky shrews. Thus on three quadrats of nearly a quarter acre each, there were 12, 10 and 6 smoky shrews collected, or an assumed average population of between 25 to 50 *Sorex fumeus* per acre. This was in the very best shrew habitat. One well wooded ravine, with a permanent cold stream and with black loamy slopes covering loose rock, appeared to be particularly attractive to these shrews. Yellow birch, mountain and striped maple, hemlock, witch hobble, with ground cover of liverworts, mosses and forest perennials, provided a cool retreat, and the black friable soil supported a particularly rich invertebrate fauna. In 1937 I trapped 70 *fumeus* during a three-week period in an area scarcely exceeding 1.5 acres. This intensive collecting had its effects, for a brief trapping period in 1939 indicated the population had been much reduced.

These high populations are exceptional, and are only met with in the most suitable habitats during years when shrews are numerous. In 1936 several quadrats in a beech woods near Ithaca, New York, on which I collected produced an estimated population of 9 and 14 *fumeus* per acre respectively.

While these shrews exhibit definite variable populations, and give every indication of being cyclic, I am not certain how long the cycle runs its course. About Cleveland, Ohio, Bole (1939) finds the smoky shrew very susceptible to drought, and believes they are affected by cycles as well. During the 1937-38 *Sorex* peak their numbers were estimated at 58 per acre, one of the highest ever discovered for any species by Bole. He remarks that in habitats other than climax forests this shrew is distinctly uncommon, the average being less than 1 per acre. Wherever I have found *Sorex fumeus*, the population has never been this low, although it is probable in some of the areas which I have trapped in western New York, the numbers of smoky shrews would not exceed 5-6 per acre.

The autumn population is composed almost entirely of young shrews, and as no breeding occurs from September until April, there is naturally some attrition during this season. Some years it may be rather high. Collecting was conducted on Connecticut Hill, near Ithaca, New York, in beech-hemlock woods with deep leaf mold. Traps were grouped in lots of 5-10 about stumps, beneath fallen logs, in leaf mold runways and kindred places. In 1,000 trap nights 155 mammals were collected, 17 being *Sorex fumeus*. During the first week of May, 1939, a similar trap line, in comparable habitat and under similar conditions was attended with markedly less success. Forty-six mammals were taken, of which 4 were *Sorex fumeus*. The population increased decidedly during the summer. From October 3 to 8, 1939, a thousand trap nights under situations comparable to the previous year produced 101 mammals, but of these 30 were smoky shrews. During the first week of May (May 1-5), 1940, the same number of traps produced 28 specimens and 6 of these were *fumeus*.

Thus we may conclude that, in these two years, scarcely more than 20 to 25% of the shrew population survived the winter. The winter mortality does not appear to be so great with the smaller rodents and *Blarina*, but even with these the loss may be 60% of the entire population.

Enemies.

Every small abundant mammal has a host of enemies; the smoky shrew has proved to be no exception.

The larger predators, such as the fox and bobcat, are known to capture and eat *Sorex*. Indeed the only item in the stomach of a large Vermont bobcat which I captured contained the entire body of a *Sorex cinereus*, and it is unlikely that they would shun *fumeus*. Hawks and more particularly owls, are known to prey upon them. Fresh pellets from a nesting pair of long-eared owls collected during June, 1926, near Ithaca, New York, contained the skulls of this species. Weasels capture considerable numbers of the long-tailed shrews (Dearborn, 1932; Hamilton, 1933). All of these larger predators probably make serious inroads on the shrew population but there is a more deadly and ubiquitous predator which possibly levies a fearful toll, and may be, in part, responsible for drastic reductions in the *Sorex* population. I refer to the ever-present *Blarina*, which may weigh two to four times as much as its smaller relative. Its greater size and formidable dentition are more than a match for the largest and strongest *fumeus*. On May 18, 1938, I caught a 20 gram *Blarina* whose stomach contents consisted entirely of the fur, flesh and toes of a smoky shrew. No *Sorex* had been captured in nearby traps, so it is good presumptive evidence that *Blarina* had overpowered and devoured its lesser kin. It is not without reason to suspect that this happens not infrequently in areas occupied by both species.

Parasites. The following parasites have been determined by the staff of the Bureau of Animal Industry, U. S. Department of Agriculture.

One seldom encounters a shrew without its quota of ectoparasites. Fleas are seldom found, and are never as abundant as they are on the larger *Blarina*. The only fleas which have been recovered from the smoky shrew are *Ctenophthalmus pseudagyrtes* and *Doratopsylla blarinae*, both commonly found on *Microtus*, *Peromyscus* and *Blarina*. Mites of the genus *Myobia*, *Haemogamasus* and *Protomyobia* (probably *P. clarapedi*) are often abundant, and immature individuals may exceed a hundred to a shrew. The small gamasid species burrow into the skin, particularly about the ears and vent, and these are the parasites which cause inflammation and pruritus. The anal region is often extensively scarred and pitted by the action of the mites.

Endoparasites apparently are restricted to a few nematodes. One, *Porrocaecum* sp., is found coiled in a sheath among the muscles, the external walls of the stomach and attached to the viscera generally. It is a sizeable roundworm, measuring 40 mm. or so in length, and there may be 10 or 12 when the infestation is heavy. It is thought that the adults occur in birds of prey but no experiments have been conducted to demonstrate this. Similar roundworms occur with great frequency in *Blarina*.

Summary.

A life history study of the smoky shrew, *Sorex fumeus*, in New York has been made over the past ten years to secure data on the biology of this little known species. Five hundred and sixteen shrews have been examined in the flesh and a number of captive animals have been studied, providing much new information on their biology.

It is shown that external measurements are of little value in determining age classes, but weight is of decided value, readily separating immature from mature individuals.

The smoky shrew undergoes a biannual molt. The change from the

gray winter pelage to the brown summer pelage occurs from late April until late June, and the fall molt occurs from mid-September to early October.

The smoky shrew is a northern species, attaining its greatest abundance in the cool forested regions of Pennsylvania, New York and New England. It is most numerous in the hardwood and coniferous forests which have a deep leaf mold.

This species is active at all hours. It is found in company with several other small mammals, whose runways it occupies. These associates are *Blarina brevicauda, Sorex cinereus, Peromyscus leucopus* and *P. maniculatus, Clethrionomys gapperi, Synaptomys cooperi, Napaeozapus insignis, Parascalops breweri* and several other species. In the habitats of this shrew where collecting has been most extensive, *Sorex fumeus* represents 18.3% of the small mammal population.

Little burrowing is done by the smoky shrew; it appears to occupy the runways of other small mammals, building its nests beneath stumps, rotted logs and in the galleries of *Blarina* and various rodents.

Sorex fumeus has diverse little notes, from high pitched grating, bat-like squeaks to indiscernible twitters. Sight and smell are not well developed, hearing is reasonably acute, but reliance is placed on the acute tactile sense.

On the basis of 168 stomach analyses, made from shrews taken throughout the year, it is concluded that insects are by far the most important food, being found in 80% of the stomachs. Vegetable matter was found in 14.9%; snails, 10.1%; spiders, 5.9%; sowbugs, 5.3%; mammals, 3.0%; salamanders, 1.8% and birds, .6%. Captive shrews maintain themselves well on an assortment of natural foods equal to half their weight daily. Captive individuals seldom drink.

The gross anatomy of the reproductive organs are described, attention being directed to the rapid increase in size of these organs at the onset of the breeding season. There are six teats, post-abdominal and inguinal in position. The mammary glands are very large, the first pair nearly encircling the body. The breeding season commences in late March and lasts through August, although only a small number of females breed in the latter month. Inasmuch as males become fecund earlier in the spring and remain so later in the summer than the females, it appears probable that the female controls the length of the breeding season. The duration of pregnancy is assumed to be somewhat shorter than three weeks. The litter size averages 5.5.

Dermal side glands are found in both sexes, but are more prominent in the males. They must bear some close relation to the reproductive period, for only at such a time do they enlarge and secrete the odorous material common to shrews.

The life span of the smoky shrew is short, for all the adults die of old age when they are 14 to 17 months old. This conclusion is based on the fact that no shrews breed in the year in which they are born, but pass their first winter as immature individuals. Weight, degree of hairs on the tail and tooth wear combined are infallible criteria of age, and serve readily to separate the adults from the immature shrews. Following the breeding season, the adult population of shrews die, usually in August.

The smoky shrew is probably a cyclic species, for its numbers fluctuate in different years. The shrew population varies from 5-50 individuals per acre during the late summer, but is much reduced during the winter, only 20-25% of the population surviving.

These shrews have many enemies, including predatory mammals and birds. It is pointed out that Blarina may be one of the most important

enemies. Ectoparasites include fleas (*Ctenophthalmus pseudagyrtes* and *Doratopsylla blarinae*), mites (*Myobia, Haemogamsus* and *Protomyobia*), while a nematode, *Porrocaecum*, is often abundant.

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EXPLANATION OF THE PLATES.

Plate I.

Fig. 1. Habitat of the smoky shrew. Beneath half-rotted logs and in the deep leaf mold of beech, yellow birch and hemlock woods, these small shrews are often numerous. In the area shown, twenty smoky shrews have been taken in a two-year period, in addition to scores of deer mice, red-backed mice, woodland jumping mice, short-tailed shrews and an occasional hairy-tailed mole. Ithaca, New York.

Fig. 2. Head of a freshly killed smoky shrew. The prominent ear, small eyes and long snout with prominent tactile hairs are characteristic of this species.

Plate II.

Fig. 3. Reproductive organs of an adult male *Sorex fumeus*. **A**, testes; **B**, caput epididymis; **C**, cauda epididymis; **D**, vas deferens; **E**, distal swelling of vas deferens; **F**, seminal vesicle; **G**, Cowper's gland; **H**, bladder; **I**, penis.

Fig. 4. Female reproductive tract of the smoky shrew. The uterus shows a condition about two weeks following partus. Four placental scars may distinctly be seen. **A**, suspensory ligament; **B**, ovarian capsule enclosing the ovary; **C**, proximal region of fallopian tube; **D**, uterine cornu; **E**, uterine vessels; **F**, bladder; **G**, diffuse prepucial glands; **H**, vulva.

Plate III.

Fig. 5. Mastology of nursing smoky shrew. The teats are always limited to three pairs in the position shown.

Fig. 6. Side glands viewed from the flesh side of an adult male *Sorex fumeus* collected on April 19, 1936. A strip of skin has been removed from the back and sides. The highly vascularized glandular area is prominent against the pale hide.

Fig. 7. Tails of immature and mature shrews. The upper figure is that of an immature shrew taken in October. Note the well-furred tip. The lower figure is that of an adult male collected in April. The absence of hairs on the tail tip and the eventual loss of hair over the entire tail, in addition to the scarring, is an indication of maturity.

Plate IV.

Fig. 8. Tooth wear in *Sorex fumeus*. **A**, an immature specimen collected on June 11 at a probable age of one month; **B**, immature shrew taken in November; **C**, sub-adult shrew collected in March, showing the prominent wear resulting in almost total loss of the brown tipped hooks of the first incisors; **D**, characteristic tooth row of mature shrew, as indicated in July and August specimens. The teeth of these old shrews have all lost their brown tips.

FIG. 1.

FIG. 2.

THE BIOLOGY OF THE SMOKY SHREW (SOREX FUMEUS MILLER).

FIG. 3.

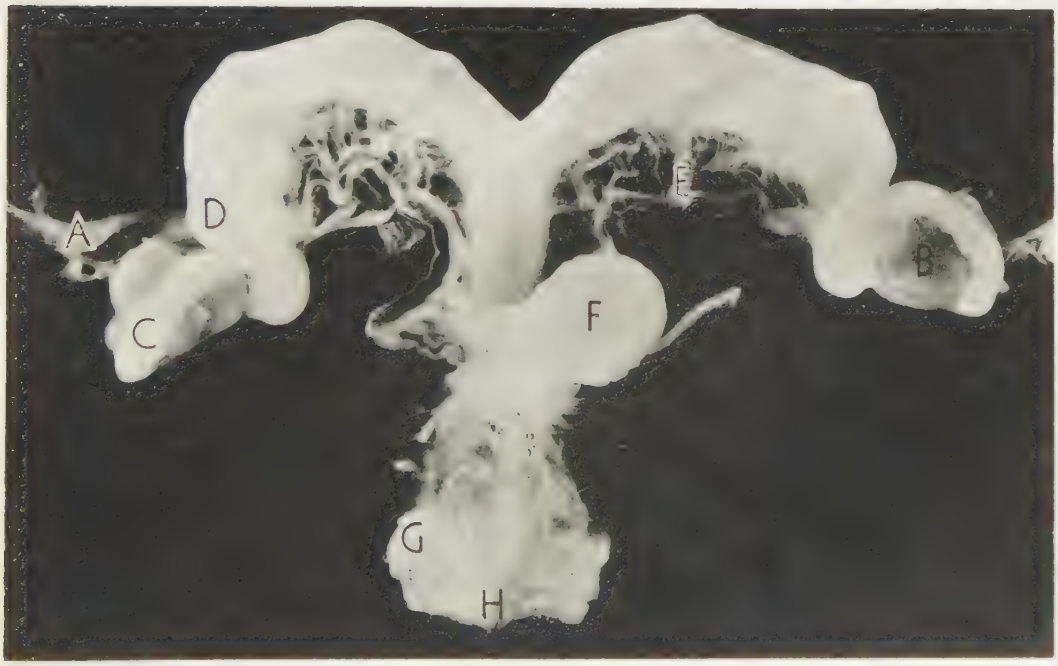

FIG. 4

THE BIOLOGY OF THE SMOKY SHREW (SOREX FUMEUS MILLER)

FIG. 5

FIG. 6.

FIG. 7

THE BIOLOGY OF THE SMOKY SHREW (SOREX FUMEUS MILLER).

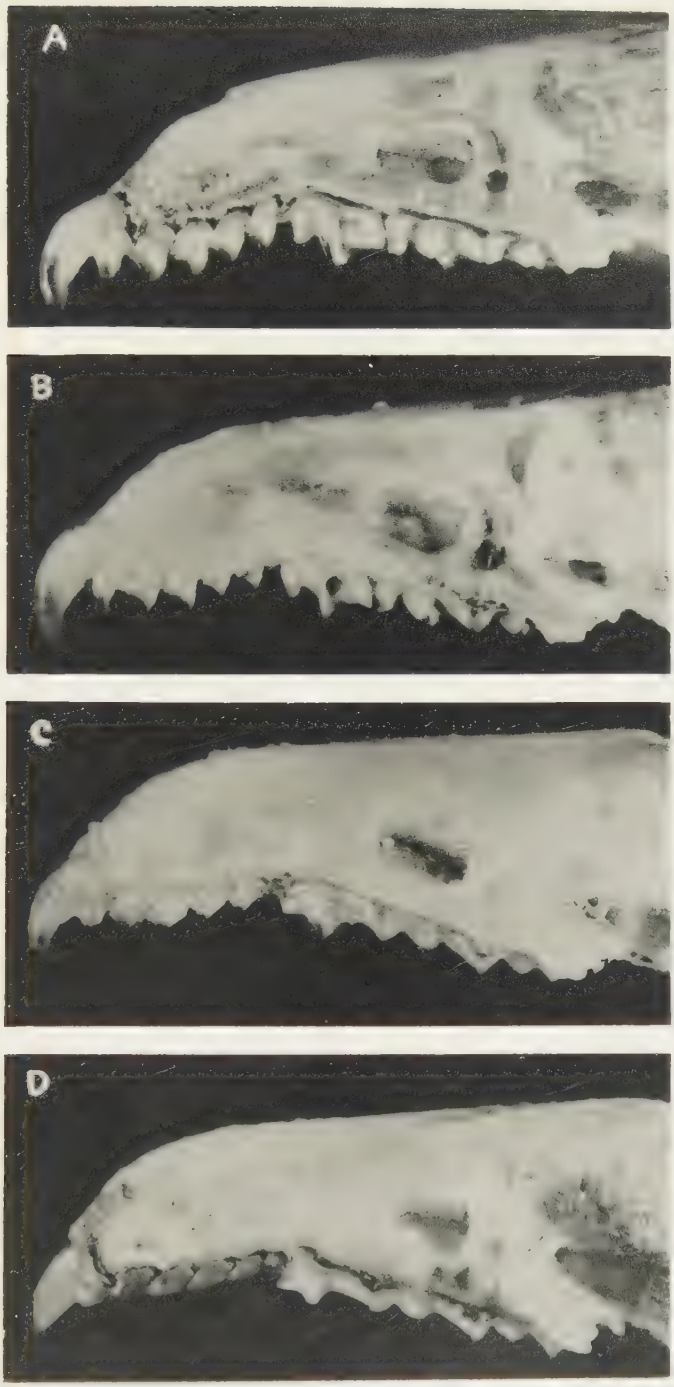

FIG. 8

THE BIOLOGY OF THE SMOKY SHREW (SOREX FUMEUS MILLER).

30.

Social and Respiratory Behavior of Small Tarpon.

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(Plates I & II; Text-figure 1).

INTRODUCTION.

As part of the program covering a study of the life history and habits of the tarpon, *Tarpon atlanticus* (Cuvier & Valenciennes), a number of small specimens were brought to the laboratories of the New York Aquarium. These were shipped from the field station of that institution on Palmetto Key, Florida, for laboratory study. They had been collected on Sanibel Island by Mr. Marshall Bishop (Breder 1939 a and b).

A consideration of the social attitudes and respiratory behavior of these specimens forms the basis of the present report. These studies have been reinforced by others made in outdoor pools, both in New Jersey and at the Florida field station.

Aside from the actual details which this study works out, the suitability of small tarpon for laboratory work early became apparent. In addition to a most remarkable hardihood, the peculiar specializations of this species lends itself, to a remarkable degree, to a variety of purposes. Some of these will become apparent on a consideration of the body of the report.

For the chemical analysis in Table X by the laboratory of the Bureau of Water Supply of New York City under the direction of Dr. F. E. Hale, we wish to express our thanks. We also wish to thank Mr. R. S. Mathews of the New York Aquarium for assistance during the course of the work.

MATERIALS AND METHODS.

In order to obtain some measure of the attitude of one fish to its fellows, two methods of approach were employed. One consisted of estimating the locomotor behavior of the fishes and the other of estimating the extent of imitation in the specialized respiratory behavior of this species.

The first method, that established by Schuett (1934) and Escobar, Minahan & Shaw (1936) and subsequently used by others, consists of estimating the amount of locomotor activity by noting the travel in a given period of the fish under observation by means of projected cubes from rulings on the glass walls of aquaria.

In these experiments rectangular metal framed aquaria of 50 liters capacity, measuring 60 x 30 x 27 cm. and containing 48 liters, were used. The four sides, which were of transparent glass, were ruled in 8 cm. squares and two mirrors were used to observe movements at the ends. Observation periods of 15 minutes were employed, the distance covered being computed from the number of projected 8 cm. cubes the fish passed through

in that amount of time. The centimeters traversed were obtained by multiplying by 8 the number of cubes traversed.

Each fish was observed for 15 minutes of each hour of a three-hour experimental period. The tarpon used in each day's experiments were selected from a group of ten specimens of the same size, about 10 cm. from the tip of the snout to the base of the tail. In general, experimental tarpon were alternated every day between the various experimental conditions of a particular series so as to distribute evenly any possible daily variations. No observations were made until at least 21 hours had elapsed after a tarpon had been placed in an experimental arrangement. The tarpon were fed chopped herring three times a week at the close of the day's experiments. In general, new water was used at the start of each set of experiments and was not changed during the course of their running. When such water was not oxygenated artifically the oxygen content was 2.0 to 2.7 cc. per liter. When oxygenated it ran from 5.6—5.8 cc. per liter.

Day by day laboratory results for all experiments were checked against the daily barometric pressure readings of the U. S. Weather Bureau, whose New York City station is located one block from the New York Aquarium. No correlations were obtained.

Tarpon respire atmospheric oxygen and for that reason rise to the surface to gulp air at more or less definite intervals. Since this feature might be useful in estimating metabolic activity, such behavior was noted along with the locomotor activity. A marked tendency to rise in groups was evident and this association of fishes in their respiratory movements was likewise studied. Since it is possible to make such studies in the field, observations on the rising of tarpon not confined in small aquaria were also taken for comparison. These field observations on rising tarpon were made in part in a private garden pool of fresh water in northern New Jersey and in part in a pool at the New York Aquarium's Florida field station. The New Jersey pool, of irregular shape, has a surface of 15 square meters and is about 60 cm. deep in its deepest part, and has a volume of 4,300 liters. The water is standing, additions being made only for evaporation, and is for most part crystal clear. The Florida pool is nearly rectangular in outline and has a surface of 115 square meters and is 1 meter deep in its deepest part. The water is standing, supplied only by rain except on the highest spring tides when sea water enters it through a narrow channel. The color is a deep tan. The volume of water is 70,000 liters.

Results of Observations on Aquarium Material.

Data obtained in the laboratory, together with their statistical analysis, are given in Tables I to V. Considering only the locomotor portions of these tables, it is evident that under the conditions of these experiments there is little or no significant difference in the locomotor activity between solitary or homotypically grouped tarpon, excepting only some indications of minimal activity in groups of two. This is in contrast to the marked differences found in other species where large differentials have been obtained. Heterotypic groups of tarpon and goldfish indicated a considerable increase in the locomotor activity of the tarpon in association with the normally more active goldfish.

Tables I to V also give the data on aquarium observations of the respiratory efforts. Like the locomotor-activity figures, these show little if any significant relationship between rises for air and various degrees of homotypic grouping. Heterotypic grouping with goldfish shows a general increase in this type of activity paralleling the increased locomotor index.

There appears to be an imitative factor in this rising to the surface for air, as the number of nearly coincidental rises in a group shows a well

marked mathematical significance. Furthermore, it will be shown that models properly manipulated will induce such rises.

Effect of Isolation, Grouping and Tonicity on Locomotor and Respiratory Activity.

Research on the goldfish, a non-schooling form, by Schuett (1934), Escobar, Minahan & Shaw (1936), Breder & Nigrelli (1938) and Shlaifer (1938) has established the fact that goldfishes are significantly more active when isolated than they are when grouped. Tarpon are, like the goldfish, non-schooling forms; however, they are definitely aggregating forms, more so than are goldfish. Accordingly, it was deemed appropriate to observe the behavior of young tarpon in isolation and in groups as regards locomotor activity. Even in well oxygenated water, tarpon rise to the surface periodically to gulp air. They possess alveolar tissue in their lung-like swim-bladder (Babcock, 1936). This pattern of respiratory behavior was employed as an indirect check on metabolic rate and the air-gulp rate (respiratory activity) was noted. Since tarpon live in both fresh and salt water, experiments were performed in both media to determine whether this difference in the chemical environmnt of the tarpon was reflected in any way in locomotor or respiratory activity.

The statistical analysis of the data in Table I indicates, in general, that there is no significant difference in locomotor and respiratory activity between a tarpon in isolation and in groups either in fresh or salt water and that locomotor and respiratory activity are, in general, the same in both media. There is, however, some indication of minimum locomotor activity in the group of two in fresh water.

Effect of Heterotypic Grouping.

When individual goldfishes were placed in various heterotypic groups of fishes (Shlaifer, 1940), the decreased activity that obtained in homotypic groups disappeared. It was thought desirable to investigate the effect of heterotypic grouping on individual tarpon, although it must be remembered that a tarpon in a group of four has the same rate of locomotor activity as does one in isolation. Tarpon were observed in isolation, in homotypic groups of two and of four and in heterotypic groups containing in one case the experimental tarpon and three orange-colored common goldfishes 10 cm. in length and in the other the experimental tarpon and three golden shiners, *Notemigonus crysoleucas* (Mitchill), colored olive-green and also 10 cm. in length. In the experiments performed on the goldfish heterotypic group and its control homotypic group, the medium was 90% fresh water and 10% sea water and it was not oxygenated, having an average oxygen content of 2.40 cc. per liter. In the experiments performed on the shiner heterotypic group and its control homotypic group, the water was completely fresh, was oxygenated with compressed air and contained 5.62 cc. of oxygen per liter.

The data in Table II again indicate minimum locomotor and respiratory activity in the homotypic group of two tarpon; especially evident, however, is the greatly increased rate of locomotor and respiratory activity in individual tarpon when in the heterotypic situations. At the same time, the data in Table II and Table III indicate that goldfishes and shiners are much more active than are tarpon. Though goldfishes differ markedly in color and to some extent in form from tarpon, shiners do not show nearly such great differences. It is probably, then, merely the disturbing effect of greater activity by the goldfishes and shiners that is responsible for increased activity in the young tarpon. At no time were goldfishes or shiners observed to chase the tarpon and thus directly affect activity. The data also show a distinctly lower rate of respiratory rises when the tarpon are in the highly oxygenated water used in the shiner experiment and its control.

Effect of Visual Contact with the Same and Other Species.

Shlaifer (1939, 1940) demonstrated that the activity of an isolated goldfish was significantly decreased when it was in contact through vision alone with others of its kind as well as when it was actually grouped with them. This line of evidence helped to establish the fact that the group effect was integrated on a visual basis. When goldfishes were grouped with various other species or were in visual contact alone with them, no diminution in activity obtained (Shlaifer, 1940). Since goldfishes and shiners do produce an increase in the activity of individual tarpon grouped with them, it was deemed desirable to pursue the analysis further by eliminating all factors but vision. Table III indicates the results.

Reference to Table III indicates that visual contact alone with goldfishes will also increase significantly the rate of locomotor and respiratory activity of isolated tarpon. In one case, IV vs. IVa, the increase in rises is not significant but from the trend probably would be so with more data. Cross-comparisons between the first parts of Table II and Table III show no significant differences for isolated fishes and those in a group of four in visual contact or grouped together. Though the volume available to the experimental tarpon in the visual contact experiments is only one-half that in Table II, there is no apparent decrease in activity. Amount of available swimming space undoubtedly affects activity in these forms but not between these limits. It will be noted that the activity of the experimental tarpon in actual grouping with three goldfishes is significantly higher than the activity of a tarpon in visual contact alone with these goldfishes. Thus, it may be concluded that while visual contact with goldfishes is enough to increase significantly the activity of isolated tarpon, it is not as effective as when the tarpon is actually grouped with them directly; presumably this is due to the greater chances for disturbing stimuli in the latter case. Additional data in Table III reveal that the goldfishes used in the experiments listed for this table had the same rate of activity as did those in Table II, although the volume available was reduced by half. The goldfishes were, however, significantly more active than the tarpon.

"Imitation" in Respiratory Behavior.

A very interesting pattern of behavior found in the tarpon is the rising to the surface to gulp air by more than one tarpon at a time in a group of two or more. One tarpon will rise to the surface and its rise may be followed immediately by that of one or more other tarpon. This imitative rise does not occur constantly, but apparently, as further data will attempt to show, only when a physiological threshhold has been reached. That such imitative rises are truly imitative and not merely coincidental may be determined by the laws of chance. An imitative rise, or at least what we consider to be one, occurs within a second after the initial rise. The minimum time between the rises of any given tarpon that are not imitative is 300 seconds; in other words, tarpon when most active in water not too well oxygenated will rise only once every five minutes. If they are less active and the water is well aerated, the interval is even greater. The data in Table IV were obtained during the running of other experiments.

The data in Table IV indicate that in a group of two, 36.8% of the time a rise by one tarpon will induce a rise by the other. In a group of four, 69.3% of the time a rise by one tarpon will induce a rise in one or more other tarpon in the group. If imitative rises do not occur at random but only when the animal is physiologically ready for an air gulp, then the results are in accordance with expectations. We find in the group of four that the percentage of induction of rises decreases as the number of fishes rising at one time increases. Presumably, the more tarpon, the less the chance that they will all be in a physiologically receptive state for the induction of imitative rises at the same time. However, comparing the group of two with the group of four it is seen that the larger the group the

greater the chance that the rise of one fish will induce an imitative rise in others. Under "additional data" in Table IV may be found evidence for the visual nature of the imitative rise. We find many cases in which the rise of a tarpon on one side of a transparent glass partition in an aquarium will produce imitative rises by tarpon on the other side.

Effect of High Oxygen Content.

Tarpon in nature may be found in salt water that is highly oxygenated and in fresh or brackish water with very low oxygen content. This experiment was designed to investigate the effect of high oxygen content on the locomotor and respiratory activity of tarpon in the laboratory. In previous experiments the water used was not artifically oxygenated and on the average contained 2.0-2.7 cc. of dissolved oxygen per liter. In this experiment compressed air was constantly bubbled through the water and maintained an average oxygen content in the aquaria of 5.81 cc. per liter.

The data in Table V, part A, again indicate no effect of grouping on activity. There is again some indication of minimum activity in the group of two but no significance statistically. When the data for locomotor and respiratory activity are compared with comparable data in Tables I and II, it is seen that while the locomotor activity is the same at the higher oxygen content, the rate of surface rises is significantly less. Thus when the oxygen content of the medium is higher, tarpon apparently utilize more dissolved oxygen and less atmospheric oxygen.

Effective Limits of the Induction of Imitative Rises.

Observations were taken upon individual experimental tarpon in a group of four in order to determine the mean and extreme ranges for non-imitative and imitative rises by the experimental animals and for rises by the non-experimental fishes which did not induce rises in the experimental. Table V, part B, lists the results.

The mean time for an imitative rise by a tarpon, following its previous rise, imitative or non-imitative, is sufficiently close to the mean time for a non-imitative rise to indicate the importance of a physiological respiratory threshhold being reached before a rise by one tarpon will induce an imitative one in another. It should be remembered that we consider a rise by a tarpon imitative only if it occurs within a second after a rise by another tarpon in the group. This is not a purely arbitrary assumption, for if the fish does not rise within one second it usually will not rise for a minute or more. The ranges from lowest to highest are great but most data fall close to the mean. It is not easy to explain these extreme ranges. Probably long periods between rises indicate greater oxygen uptake at the last gulp and very short periods indicate very low oxygen uptake. It will be noted from the column titled "mean activity per minute" that at the extreme ranges in the last column the activity per minute (obtained by dividing the centimeters by the number of minutes) does not differ markedly from these means and hence would eliminate the possibility that very low or very high rates of activity were responsible.

Induction of Imitative Rises by a Tarpon Model.

While it is known that the rising of a tarpon to the surface to breathe air may induce an imitative rise in others in a group, it was thought desirable to determine whether such imitative rises could be induced by objects other than the fish themselves. Accordingly, the following experiment was performed:

Four tarpon were placed in water 90% fresh and 10% salt. The average temperature was 21 degrees C. and the average oxygen content 2.69 cc. per liter. Attempts were made to induce rises in the tarpon by periodically

raising to the surface in a typical tarpon respiratory rise a carved wooden model. This model was 10 cm. long, painted silver, and was a reasonably accurate though rough duplication of a tarpon in general body form. It had no fins, eyes nor mouth and was manipulated by the observer by means of two strings tied at its opposite ends.

Many attempts were unsuccessful, as is to be expected if a tarpon does not respond imitatively even to another of its kind unless it has reached a respiratory threshhold. However, over a period of 12 hours of observation there were 47 successful inductions of rises in one or more tarpon. The average time for such imitative rises by a tarpon following its last rise was 4.35 minutes. The lowest elapsed time was 1.50 minutes and the highest was 12:00 minutes.

Results of Observations on Pool Material.

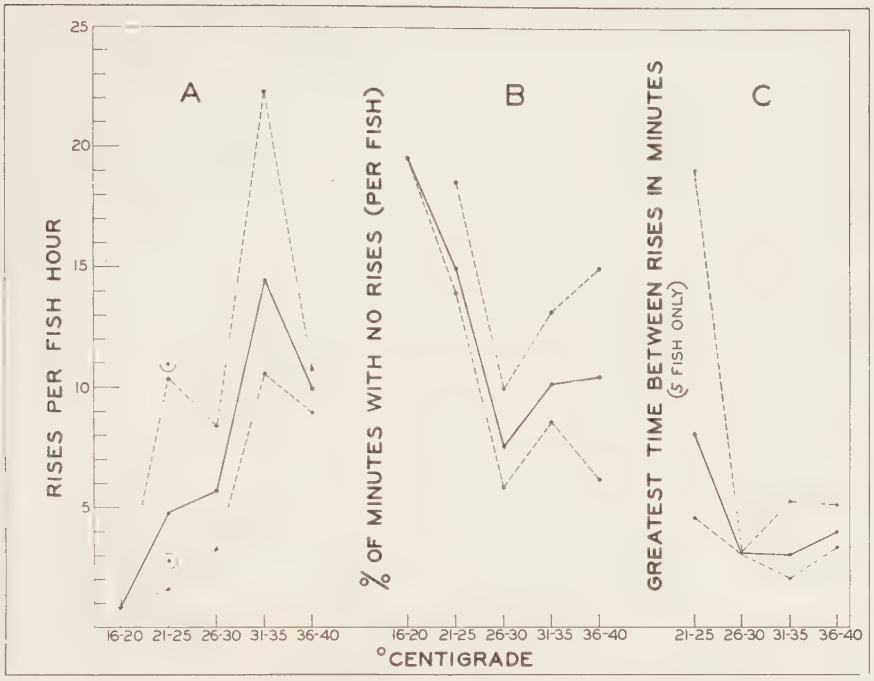
Data obtained in the field, together with analysis, are given in Tables VI to X. Under the conditions, estimates of locomotor activity were impossible, resulting in the confinement of these studies to the respiratory efforts of the tarpon. These fish were mostly of larger size than the aquarium material, the measurements being given in the tables.

"Imitation" in Respiratory Behavior.

The figures obtained on "imitative" rises in the two pools studied are in general agreement with those observed in small aquaria, differing only in the lesser extent of the imitation, Table IX. Since these pools were much larger and the fish able to retreat much further from each other and since the other centrifugal influences of the outdoors were present, this is exactly what should be expected. In accordance with this it is evident that there is a tendency for more fish to rise in groups in closer confinement or larger groups. This, again, would be expected, in that a greater opportunity of seeing a fish rise spontaneously is directly proportional to the number present in a given body of water.

Effect of Temperature on Respiratory Behavior.

In the laboratory the temperature differences were not great enough to give any measurable difference in the number of rises for respiratory purposes relative to thermal differences in the environment. With the large temperature differentials found in the outdoor pools, it was possible to establish a relationship between temperature and the amount of aerial respiratory activity encountered. Table VIII gives the rises per fish per hour tabulated according to the temperature scale in steps of 5 degrees Centigrade. Text-figure 1 illustrates some of the correlations between temperature and various elements in the respiratory rises of these practically wild fish. Table VIII and Graph "A" in this figure show a consistent increase in the number of rises per hour with an increasing temperature, from the lowest temperature to which the fish could be safely subjected without endangering their lives, 16° to 20° C., to a range of 31° to 35° C. Above this, 36° to 40°, which is close to their upper thermal limits, the respiratory rises actually fell off. At this temperature range there was, however, a marked difference in their activity. At the ranges lower than this one they swam about actively, which activity no doubt contributed to their respiratory needs and consistently added to their basic metabolic rate at any given temperature. At this higher level, however, they rested quietly in one place, evidently uncomfortable and making no more effort than was necessary to rise periodically to the surface. This is interpreted to mean that the inhibiting influence on their activity of this high temperature actually reduced their oxygen demand below that at the next lower temperature range where they were normally active.



Text-fig. 1.

Comparison of the respiratory behavior of small tarpon according to temperature in outdoor pools.

The solid line in this chart indicates the mean value as taken from Table VIII while the two dotted lines indicate the maximum and minimum values obtained.

Practical considerations made it impossible to take oxygen readings of the waters of these two pools at the time the observations were made. However, since both were supporting other fishes which are not able to respire air at the same time, they were clearly not near an anaerobic condition. Aquarium experiments in which oxygen content was measured showed that at a content of 2.5 cc. per liter, tarpon rose on the average of 11 times per hour in the 21° to 25° range. This is higher than any reading in the field, where we have good reason to suppose that the oxygen content was at all times considerably above that figure. In similar aquarium experiments at an oxygen content of 5.7 cc. per liter, the same fish rose on an average of 2.8 times per hour. This value is between the mean and minimum of the field observations, and there is reason to suppose that the field conditions more closely approached the latter figure than the former. These two values are indicated on Text-figure 1 by circled dots. It is noteworthy in this connection that the thermally lower parts of this chart were taken in New Jersey and the higher in Florida. Considering the differences in the dissolved salts in these two waters (see Table X), it is rather remarkable that the entire line is so consistent, tending to confirm the aquarium observations with regard to the apparent indifference that these fishes show to the tonicity of their environment.

The field observations were each made for stated periods and tabulated by minutes. Consequently there were always some whole minutes which were represented on the note sheet by blanks. If a similar graph, "B" in Text-figure 1, is plotted showing these minutes without rises, expressed as

percentage of an hour, against a temperature scale, a line is obtained approximately the inverse of that of "A." It is, however, clearly not its mirror image and has the advantage of showing certain features not evident in the former. It, among other things, takes into account the manner of the grouping of the rises and smooths out a simple count of the number in an hour, since it is a measure of arbitrary units (minutes during which the tarpon were "holding their breath." If the imitative efforts of the tarpon modified this need for air seriously, this line should not so closely agree with the first. For example, fish rising a minute or more apart, as compared with all working within one minute in approximate synchronization, would result in vastly different lines. It is notable in this connection that while the number of rises per hour in "A" shows greater consistency (spread between minimum and maximum) in the highest temperature range, in "B" there is a reverse effect, this range showing the greatest spread, indicating that while the fish are probably doing little more than answering physiological needs they are at the same time paying less attention to their fellows.

These data may be handled in still a third way. If the greatest elapsed time between rises in minutes and seconds be plotted against a temperature scale, we obtain a line showing still other tendencies. For practical reasons the figures on this graph are limited to observations concerning five fish. This figure "C" in Text-figure 1 has rather different characteristics and actually the solid line of means is less valuable for consideration than the dotted maximum and minimum, for reasons given below. The line showing the maximum time between rises recorded is a measure of how long the fish can "hold their breath" and actually gives an estimate of the physiological needs of the fish apart from its socialized imitative behavior. The minimum line on the other hand gives an estimation of how soon a fish will follow a fellow to the surface after already having filled his "lung." In other words, this line is more of an index of social attitude than of respiratory need. Thus the mean becomes a time of averages between physiological demand and social influence. It is notable in this connection that the greatest spread between "physiological need" and "sociability" is registered in the lowest temperature range measured. This is interpreted to mean that while tarpon can hold their breath a long time at this temperature, they are also at liberty to be fully social. The line of "maximums" drops sharply with increased temperature, as should be expected from what we have already seen in "A" and "B." The line of "minimums" remains relatively closer to a horizontal line, indicating that their attitude toward their fellows is much less influenced by temperature than is their need for oxygen. It is noteworthy that the time of their greatest sociability is also at the range of their greatest respiratory activity, 31° to 35° C.

A considerable amount of differential behavior was noted in these field observations which is not amenable to statistical treatment.

For example, the pool at the Palmetto Key laboratory showed marked variations in the physical environment from time to time. None of the figures in the calculations show any significant differences associated with these changes, although the observed behavior of the tarpon was distinctly different.

At times when the surface of the water was clear and mirror-like, the fishes generally took their air with a resounding gulp and considerable agitation of the water. The surface disturbance so made is shown in Plate I, Figure 1. The center of the major circle is where the head protruded and the lesser one, to the right, was caused by the tail. This is typical of the rises at such times.

At other times the surface was covered with a scum of green algae that at times formed into a complete blanket. During the processes of formation the rises were much less evident and usually made without any tail splash. Plate I, Figure 2, shows the conditions during the formation of

such an algal scum. A fish had just risen to the left of center. This represents about the maximum disturbance under such conditions.

Later when the scum completely covered the pool, the disturbance incident to rises was even less. The algal blanket was such that it entrained and held the exhaled air, which floated on the surface for some minutes as bright green bubbles. This condition is shown in Plate I, Figure 3. The various bubbles are almost entirely from tarpon exhalations. As the fish normally emit a bubble from each gill opening, these were frequently seen as paired bubbles. The two largest to the left of center are such a pair, from the most recent rise.

While some of these features are referable to the physical condition of the water, the impression was gained that the tarpon disliked coming in contact with the green scum any more than was necessary, avoiding the usual tarpon "roll" of clear water.

Discussion.

Since differences in the locomotor behavior of fishes may be used as one kind of measure of their mental state or psychic attitude toward their fellows, the recent development of a simple method of estimating these differences has stimulated work along such lines. Up to the present all species used for this type of study have shown distinct differences in the amount of locomotion in association with various groupings, homotypic or heterotypic. The species used have been *Carassius auratus,* Schuett (1934), Escobar, Minahan & Shaw (1936), Shlaifer (1938, 1939, 1940) Breder & Nigrelli (1938); *Gambusia affinis,* Escobar, Minahan & Shaw (1936). All considered the extent of travel per unit of time. In addition, Breder & Nigrelli (1938) considered the configurational pattern in three dimensional space and found similar differentiable behavior.

With this as a background, it came somewhat as a surprise to find that the tarpon, a markedly aggregating form, gave no mathematically significant figures from its locomotor behavior when alone or in aggregations. If such is present, it is extremely feeble as compared with the species previously studied, as all studies have been based on a reasonably comparable amount of data. It thus appears that this method may or may not be useful merely on a basis of whether it "works." Evidently fishes are no more uniform from group to group in this regard than they are in others.

This, obviously, is not to say that tarpon are indifferent to one another, for even a most superficial examination will show their strong aggregating tendency. Very possibly the difficulty lies in their relative inactivity as compared, for example, to the goldfish or shiners. When in the presence of the latter they show a marked increase in travel. That this relative inactivity is not merely a condition imposed by close confinement is evident when it is considered that in the garden pool of clear water their behavior was closely similar to that of the small aquaria; *i.e.,* at nearly all times they were quietly aggregated in a relatively compact group, spaced about as they were in the aquarium.

That the metabolic rate is not vastly different under various conditions of grouping is shown by the similarity of their rising to breathe under different groupings; it rises notably only in the presence of goldfish, which no doubt is a result of their greater muscular exertions incident to their increased activity in swimming. Thus we are obliged to leave this portion of the study with the conclusion that the method of estimating social attitude from a basis of locomotor activity is not useful in estimating the social attitude of tarpon, on a purely pragmatic basis.

Since tarpon will rise to breathe air for purely physiological reasons and will also imitate each other in this item of behavior, there are thus two elements involved. While the full separation of them would be exceed-

ingly difficult, it has been shown in the tables that there is a high degree of imitation involved.

Very low oxygen concentrations induce more rises per hour, as would be expected, but grouping and changes in volume seem to have little effect. An unknown variable that must be considered in this connection is the amount of air exchanged on any given gulp. Judging from the figures, however, this would seem to have scant bearing on the social part of this behavior. The work of Shlaifer (1939) on the oxygen consumption of the goldfish, in which he showed that the rate varied with the grouping, could only be used in the present species in a properly arranged metabolic chamber, since both aerial and aquatic respiration are involved. As evidenced by the social factors to be seen in the rising behavior, such a study should be expected to give similar results.

In all these observations a rise has been considered imitative only if made a second or less after the initial rise. Those of a larger time interval have been considered independent. The question arises as to how long such behavior can be considered imitative, or, in other words, what of the memory image and inhibiting influences that give delayed responses? It would seem that first the tarpon must be in a physiologically receptive state, *i.e.*, have not recently gulped air, for two gulps in rapid succession have never been noted. Thus, if a tarpon has partly used up its air supply it may respond with more or less immediateness on the sight of an individual rising to breathe in response to a purely physiological need.

Summary.

1. The locomotor behavior of tarpon is not a useful index in estimating their homotypic group behavior, nor is the extent of their rising to the surface to breathe.
2. There is a marked tendency toward imitation in tarpon rising to breathe, which is of social rather than physiological significance. More or less crude models properly manipulated will induce rises to breathe.
3. Observations in the field, checked against those in small aquaria, agree as to respiratory behavior and indicate the validity of the use of small aquaria for such purposes.
4. Goldfish and shiners, which are more active, induce in tarpon a marked increase in both locomotor and respiratory activity, as do goldfish with which tarpon are in contact through vision alone.
5. Environmental changes including barometric, chemical (salt and fresh water) and capacity of aquaria, do not significantly change the locomotor or respiratory behavior of tarpon, but a large reduction in dissolved oxygen increases respiratory activity. Large temperature changes also result in the alteration of the respiratory activity.

TABLE I.

Effect of Grouping on the Locomotor and Respiratory Activity of Small Tarpon.

Exp. Cond.	I. In Isolation			II. In Group of Two			IV. In Group of Four		
	Mean Activity[3]	Mean No. of Rises[4]	Cm. per Rise	Mean Activity[3]	Mean No. of Rises[4]	Cm. per Rise	Mean Activity[3]	Mean No. of Rises[4]	Cm. per Rise
A[1]	480.0	2.9	165.5	524.0	2.8	187.1	433.6	2.5	173.4
B[2]	418.4	2.6	160.9	312.0	2.3	135.6	473.6	3.0	157.8

Statistical Analysis in P-Values[5].

Exp.	I vs. II		I vs. IV		II vs. IV		I A[6] vs. I B		II A vs. II B		IV A vs. IV B	
Cond.	Activity	Rises	Activity	Rises	Activity	Rises	Activity	Rises	Activity	Rises	Activity	Rises
A	0.5570	None[7]	0.4589	0.4823	0.0908	0.5525	0.5444	0.5255	0.0007	0.4823	0.4472	0.4706
B	0.1292	0.5570	0.4765	0.4940	0.0100	0.1631						

[1] Volume is 48 liters of *sea water* in a 50-liter aquarium.

[2] Volume is 48 liters of water, 90% fresh, 10% salt, in a 50-liter aquarium.

[3] Expressed in centimeters traversed per fish per 15-minute period of observation. In this and subsequent tables all figures listed under *mean activity* and *mean number of rises* refer to the average for each individual in the particular experimental condition and in each group forty-eight 15-minute periods of observation were divided equally among the number of fishes present when these were tarpon grouped together.

[4] Expressed in surface rises to gulp air per fish per 15-minute period of observation.

[5] Upper limit of statistical significance is set at 0.05. This is three times the probable error. P = 0.01 indicates good significance, while a value of 0.100 or more indicates little significance.

[6] Letter refers to the experimental condition.

[7] Indicates no significance calculated, since means are almost identical.

TABLE II.

Effect of Isolation, Homotypic and Heterotypic Grouping on the Locomotor and Respiratory Activity of Small Tarpon[1].

Part A—Goldfish.

I. In Isolation			II. In Homotypic Group of Two			IV. In Homotypic Group of Four			IVa. In Heterotypic Group of Four[2]		
Mean Activity[3]	Mean No. of Rises[4]	Cm. per Rise	Mean Activity[3]	Mean No. of Rises[4]	Cm. per Rise	Mean Activity[3]	Mean No. of Rises[4]	Cm. per Rise	Mean Activity[3]	Mean No. of Rises[4]	Cm. per Rise
496.0	2.1	236.1	221.6	1.0	221.6	586.4	2.7	217.1	1753.6	6.9	254.1

Statistical Analysis in P-Values.

I vs. II		I vs. IV		I vs. IVa		II vs. IV		II vs. IVa		IV vs. IVa	
Activity	Rises	Activity	Rises	Activity	Rises	Activity	Rises	Activity	Rises	Activity	Rises
0.0002	0.0036	0.1900	0.2476	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Part B—Shiners.

V. In Homotypic Group[6]				Va. In Heterotypic Group[7]			Mean Activity of Non-test Tarpon in Homotypic Group[8]	Mean Activity of Non-test Shiners in Heterotypic Group[8]
Exp. Cond.[5]	Mean Activity[8]	Mean No. of Rises[9]	Cm. per Rise	Mean Activity	Mean No. of Rises	Cm. per Rise		
A	289.6	0.6	816.0	938.4	1.1	853.1	470.4	3360.2

Statistical Significances.
V vs. Va—Activity—.0134
V vs. Va—Rises—.0374
Non-test Tarpon vs. Non-test Shiners—Activity—.0000

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[1] Volume is 48 liters of water, 90% fresh and 10% salt, in a 50-liter aquarium.
[2] Consists of experimental tarpon and three goldfish, *Carassius auratus* (Linnaeus).
[3] See Footnote No. 3 of Table I.
[4] Expressed in surface rises to gulp air per fish per 15-minute period of observation.
[5] Volume is 48 liters of water, 100% fresh, in a 50-liter aquarium. Temperature is 71 degrees F. Average oxygen content 5.62 cc. per liter.
[6] Experimental tarpon is grouped with three other tarpon.
[7] Experimental tarpon is grouped with three golden shiners, *Notemigonus crysoleucas* (Mitchill).
[8] Expressed in centimeters traversed per fish per 15-minute period of observation. Figure given is the mean of forty-eight 15-minute periods.
[9] Expressed in surface rises to gulp air per fish per 15-minute period of observation. Figure given is the mean of forty-eight 15-minute periods.

TABLE III.

Effect of Visual Contact with the Same and Other Species upon the Locomotor and Respiratory Activity of Isolated Small Tarpon[1].

I. In Total Isolation			IV. In Visual Contact with Three Tarpon			IVa. In Visual Contact with Three Goldfish		
Mean Activity[2]	Mean No. of Rises[3]	Cm. per Rise	Mean Activity[2]	Mean No. of Rises[3]	Cm. per Rise	Mean Activity[2]	Mean No. of Rises[3]	Cm. per Rise
555.2	3.1	179.1	510.4	3.7	137.9	944.8	5.3	178.2

Statistical Analysis in P-Values.

I. vs. IV.		I. vs. IV.a		IV. vs. IV.a	
Activity	Rises	Activity	Rises	Activity	Rises
0.5381	0.4300	0.0001	0.0048	0.0000	0.206

Statistical Analysis of Cross-comparisons Between Tables IIA and Above in P-Values.

I.(2)[4] vs. I.(3)		IV.(2) vs. IV.(3)		IVa.(2) vs. IVa.(3)	
Activity	Rises	Activity	Rises	Activity	Rises
0.4246	0.0832	0.2476	0.5570	0.0000	0.0340

The Locomotor Activity[5] of the Non-Test Animals In Tables IIA and Above.

III. Three Goldfishes of IVa, Table II	IIIa. Three Goldfishes of IVa, Table III	IIIb. Three Tarpon of IV., Table III		
			Mean No. of Rises[6]	Cm. per Rise
2647.2	2538.4	514.4	2.4	214.3

Additional P-Values.

III (Table III) vs. IIIa (Table III)—0.5570
III (Table III) vs. IV (Table II A)—0.0000
IIIa (Table III) vs. IIIb (Table III—locomotor activity)—0.0000
IIIb (Table III—locomotor activity) vs. IV (Table II A)—0.1869
IIIb (Table III—rises) vs. IV (Table II A)—0.4823

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1 Volume is 48 liters of water, 90% fresh and 10% salt, in a 50-liter aquarium. Transparent glass divides the aquarium into two compartments of 24 liters each. Experimental tarpon is in one compartment and the non-test animals in the other.
2 See Footnote No. 3 of Table I.
3 Expressed in surface rises to gulp air per fish per 15-minute period of observation. See Footnote No. 3 of Table I.
4 Arabic numeral refers to the number of the Table.
5 Expressed in centimeters traversed per fish per 15-minute period of observation. Figure given is mean of forty-eight 15-minute periods. Based on data obtained during the respective experiments.
6 Expressed in surface rises to gulp air per fish per 15-minute period of observation. Figure given is mean of forty-eight 15-minute periods.

TABLE IV.

Degree of Imitation in Respiratory Activity[1].

Fish Rises	A[2] In Group of Two No. of Rises	B[3] In Group of Two No. of Rises	C[4] In Group of Two No. of Rises	A, B and C combined In Group of Two No. of Rises	%
Alone	40	40	66	146	63.2
With one Companion	48	15	22	85	36.8
	In Group of Four	In Group of Four	In Group of Four	In Group of Four	
Alone	38	13	52	103	30.7
With one Companion	37	21	39	97	29.0
With two Companions	31	9	44	84	25.1
With three Companions	11	1	39	51	15.2

Additional data.

Of 177 rises of isolated tarpon in IV of Table III, 23 were induced by the rises of the three tarpon with which it was in visual contact.

In 23 instances out of 218, the rises of the isolated tarpon in IV of Table III induced rises in the tarpon with which it was in visual contact.

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[1] All observations taken on homotypic groups of tarpon.
[2] Data based on observations taken during the running of A of Table I.
[3] Data based on observations taken during the running of B of Table I.
[4] Data based on observations taken during the running of the experiments of Table IIA.

TABLE V.

Effect of Various Factors on Small Tarpon.

Part A. Effect of High Oxygen Content on the Locomotor and Respiratory Activity of Isolated and Grouped Tarpon.

Exp. Cond.	I. In Isolation			II. In Group of Two			IV. In Group of Four		
	Mean Activity[2]	Mean No. of Rises[3]	Cm. per Rise	Mean Activity[2]	Mean No. of Rises[3]	Cm. per Rise	Mean Activity[2]	Mean No. of Rises[3]	Cm. per Rise
A[1]	488.0	0.7	697.1	336.8	0.5	673.6	637.4	0.8	796.7

Statistical Analysis and Cross-Comparisons in P-Values.

Exp. Cond.	I vs. II		I vs. IV		II vs. IV		I(5) vs. I(1B+2)[4]		II(5) vs. II(1B+2)		IV(5) vs. IV(1B+2)	
	Activity	Rises	Activity	Rises	Activity	Rises	Activity	Rises	Activity	Rises	Activity	Rises
A	.1236	.1786	.4392	.5596	.0686	.1236	.3858	.0002	.1868	.0004	.1731	.0000

Part B. The Extent to Which the Respiratory Activity of Tarpon in a Group may be Induced by "Imitation."[5]

Type of Rise	Number of Rises	Mean Activity between Rises	Mean Time between Rises	Mean Activity per Minute	Range in Time and Activity[9]
A[6]	149	318.4 cm.	7.87 min.	40.40 cm.	Lowest—1.75 min. 64 cm. Highest—51.50 min. 912 cm.
B[7]	160	236.8 cm.	5.74 min.	41.20 cm.	Lowest—0.41 min. 48 cm. Highest—39.0 min. 1560 cm.
C[8]	358	263.2 cm.	5.38 min.		Lowest—0.25 min. 24 cm. Highest—36.00 min. 1480 cm.

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1 Volume is 48 liters of water, 90% fresh and 10% salt, in a 50-liter aquarium. Temperature 74 degrees F. Average oxygen content—5.81 cc. per liter.

2 Expressed in centimeters traversed per fish per 15-minute period of observation. Figure given is the mean of forty-eight 15-minute periods.

3 Expressed in surface rises to gulp air per fish per 15-minute period of observation. Figure given is the mean of forty-eight 15-minute periods.

4 Number in parentheses refers to the number of the Table and the letter to the experimental condition.

5 Tarpon kept in a group of four in 48 liters of water, 90% fresh and 10% salt, in a 50-liter aquarium. Temperature 74 degrees F. Average oxygen content 2.69 cc. per liter. Six experimental fish were observed for a total of 20 two-hour periods.

6 "Non-imitative." Experimental fish rises alone and may or may not induce imitative rises in the non-experimental fishes. (Time and acitvity records last in each case from the completion of one rise to the start of another.)

7 "Imitative." Experimental fish rises within one second of the rising of another fish or other fishes in the group of four.

8 Rises of non-experimental fishes which do not induce rises in the experimental. The number of rises refers to the rises of one or more fishes at a time of the non-experimental group. The activity and time, however, refer to the experimental fish.

9 In A and B the range indicates the smallest and largest periods of time and degree of activity in which the experimental animal will rise alone or imitatively from the time of its last rise. In C the figures indicate the smallest and largest periods of time and degree of activity in which rises of fishes in the group will *not* induce rises in the experimental fish following the last rise.

TABLE VI.

Respiratory Activity in a Fresh-Water Pool in New Jersey[1].
(One-half Hour Observation Periods).

Date	Time	°C	No. Fish	No. of rises of all fish to surface in groups of: 1	2	3	4	5	6	7	8	9	Total
6/8[2]	1:28	24	5	3	6	6	0	0	—	—	—	—	15
6/8[2]	2:04	24	5	6	10	6	4	0	—	—	—	—	26
6/9[3]	11:00	24	5	1	0	3	0	0	—	—	—	—	4
6/9[3]	11:45	24	5	5	0	0	0	0	—	—	—	—	5
6/9[4]	3:40	23	5	8	4	3	0	0	—	—	—	—	15
6/9[4]	4:16	23	5	3	2	3	0	0	—	—	—	—	8
7/14[5]	11:21	21	5	13	0	0	0	0	—	—	—	—	13
7/14[5]	11:51	21	5	10	0	0	0	0	—	—	—	—	10
7/20[6]	2:35	26	9	11	4	0	0	0	0	0	0	0	15
7/20[6]	3:05	26	9	16	4	3	0	0	0	0	0	0	23
8/25[7]	11:00	18	5	0	2	0	0	0	—	—	—	—	2

Calculations.

Rises per fish hour	Fish rising in groups by percent of total: 1	2	3	4	5	6	7	8	9	All	Minutes without rises in percent[8] Per fish
6.0	20	40	40	00	00	—	—	—	—	73	14.6
10.4	24	37	24	15	00	—	—	—	—	57	11.4
1.6	25	00	75	00	00	—	—	—	—	93	18.6
2.0	100	00	00	00	00	—	—	—	—	83	16.6
6.0	54	26	20	00	00	—	—	—	—	73	14.6
3.2	38	25	37	00	00	—	—	—	—	83	16.6
5.2	100	00	00	00	00	—	—	—	—	70	14.0
4.0	100	00	00	00	00	—	—	—	—	70	14.0
3.3	73	27	00	00	00	00	00	00	00	63	7.0
5.1	70	17	13	00	00	00	00	00	00	53	5.9
0.8	00	100	00	00	00	—	—	—	—	98	19.6

[1] Fish used in this experiment: 9.5, 12.5, 11.25, 10.25, 10.75 cm. in standard length, placed in pool June 7. Added July 19: 11.1, 10.0, 11.9 cm. in standard length. This pool, recently made of concrete, is fed from a pipeline running from a private home. Water lillies and some *Lebistes reticulatus*, together with an occasional volunteer *Rana catesbiana*, make up the remaining fauna.

[2] Fish remaining in deepest part of pool in a small aggregation. Partly cloudly with a slight haze; light s-w breeze. Rain threatening.

[3] Fair with light easterly breeze. Rain had fallen from 7:00 to 10:00 a.m.

[4] Thunder with rain threatening. Hazy and overcast. A small trickle of fresh water entering pool. Rain began at 4:35 p.m.

[5] Sun bright, water crystal clear. Fish active, swimming in a larger group than before, over an area of about 4 ft. in diameter.

[6] Humid and partly overcast; hazy. Light drizzle at 2:40 p.m. Fish in n-w corner, rising very quietly. Fish near surface for most part.

[7] Cloudy, chilly. Weather has been unseasonally cold for some time.

[8] Based on initial data, not shown in first part of table.

TABLE VII.

Respiratory Activity in a Brackish Water Pool in Florida[1].
(One Hour Observation Periods).

Date	Time	°C	No. fish	Number of rises of all fish in groups of: 1	2	3	4	5	Total
6/23[2]	9:27	33.5	5	31	22	15	8	5	81
6/25[3]	9:42	30.5	5	29	8	6	0	0	43
6/26[4]	9:52	33.0	5	25	16	12	0	0	53
6/26[5]	4:52	36.5	5	25	16	12	0	0	53
6/29[6]	9:34	34.0	5	50	16	3	0	5	74
6/29[7]	3:31	39.0	5	34	6	3	4	0	47
6/30[8]	11:58	37.0	5	20	18	12	4	0	54
7/1[9]	9:25	33.5	5	13	12	9	4	5	43
7/2[10]	2.27	36.0	4	30	6	0	0	—	36
7/4[11]	11:52	34.0	3	67	0	0	—	—	67

Calculations.

Rises per fish hour	Fish rising in groups by percentage of total: 1	2	3	4	5	Minutes without rises in percent[13] All	Per fish
16.2	38	28	18	10	06	43	8.6
8.6	67	19	14	00	00	50	10.0
10.6	47	30	23	00	00	46	9.2
10.6	47	30	23	00	00	51	10.2
14.8	68	22	04	00	06	31	6.2
9.4	72	13	06	09	00	50	10.0
10.8	37	33	22	08	00	53	10.6
8.6	30	28	21	09	12	66	13.2
Mean[12] 11.2	52	25	16	04	03	49	9.8
9.0	83	17	00	00	—	60	15.0
22.3	100	00	00	—	—	30	10.0

[1] This pool, actually an old alligator hole, which had been artificially enlarged two years previous, is connected with the sea by a cut channel and receives sea water only at the highest spring tides. This channel is choked with fallen palmetto leaves, effectively preventing the passage of even small fish. The pool is usually sufficiently fresh for the island fauna to use for drinking purposes. These include various birds, coons and gopher tortoises. See Table X for analysis of this water. *Gambusia, Mollienesia, Cyprinodon* and both fiddler and blue crabs make up the remainder of the aquatic fauna.

[2] Clear and sunny. Water turbid; reddish colored. The fish used in this experiment measured 48.89, 31.16, 33.02, 30.48, 29.21 cm. in standard length. The first two were removed in the order listed and had been placed in pool March 26, 1939, not having been disturbed since then.

[3] Sky overcast, distant thunder. Pool covered with scum of algae, forming bright green bubbles wherever tarpon rolled. Fishes rising very quietly.

[4] Rain most of previous night. Green scum on pool much reduced. Water much clearer.

[5] Clear, shadows of palmettos reaching pool. Algal scum forming again. Fish scattered out all over pool. Formerly in deepest part.

[6] Light clouds passing over sun. Scum no longer green; grayish-brown. A little rain previous night. Tarpon rolling all over pool.

[7] Clear. Surface of pool cleaner. Tarpon making vigorous splashes.

[8] Clear. Surface still cleaner. Fish roll well but lazily.

[9] Clear. Scum as day before.

[10] Clear. Scum completely gone from pool. Day before fish had been caught and measured. One died. Rain in the morning. Fish rising in all parts of pool.

[11] Clear. Spring tides. Day before, after the observation period, salt water entered and as this observation was being made water was again running in. Some slight scum on water. Another fish died. Fish feeding vigorously all around edge. Rain previous night. Pool overflowing banks in places. Fish widely scattered.

[12] The preceding footnotes indicate why, with the changed conditions, the last two periods have been omitted from some of the calculations.

[13] Based on initial data, not shown in first part of table.

TABLE VIII.

Temperature and Rises in Pools.

Calculations Based on Tables VI and VII.

Behavior	Temperature in 5° intervals centigrade				
	16-20	21-25	26-30	31-35	36-40
Rises per fish hour	0.8	6.0	3.3	16.2	10.6
		10.4	5.1	10.6	9.4
		1.6	8.6	14.8	10.8
		2.0		8.6	9.0
		6.0		22.3	
		3.2			
		5.2			
		4.0			
Mean	0.8	4.8	5.7	14.5	10.0
Maximum	0.8	10.4	9.6	22.3	10.8
Minimum	0.8	1.6	3.3	8.6	9.0
% minutes without rises, per fish	19.6	14.6	7.0	8.6	10.2
		11.4	5.9	9.2	6.2
		18.6	10.0	10.0	10.6
		16.6		13.2	15.0
		14.6		10.0	
		16.6			
		14.0			
		14.0			
Mean	19.6	15.0	7.6	10.2	10.5
Maximum	19.6	18.6	10.0	13.2	15.0
Minimum	19.6	14.0	5.9	8.6	6.2
Greatest unit of time between rises in minutes and seconds[1]		6:46	3:10	2:61	4:31
		4:57	3:16	2:40	4:18
		19:18	*6:03*	3:43	3:23
		8:33	*6:05*	3:22	5:14
		5:08		2:57	5:02
		8:18		2:05	3:41
		7:26		5:09	*4:20*
		5:07		5:34	*4:01*
				3:16	
				2:44	
Mean of all		8:07	4:09	3:43	4:04
Maximum		19:18	6:05	5:34	5:14
Minimum		4:57	3:10	2:05	3:23
Mean (5 fish only)		8:07	3:13	3:04	4:01
Maximum		19:18	3:16	5:34	5:14
Minimum		4:57	3:10	2:05	3:41

[1] In this tabulation, the hour periods of the brackish water pool have been divided in two and read as recorded. All entries refer to groups of five fish except those in italics. From left to right these groups are of 9, 3 and 4 fish respectively.

TABLE IX.

Comparison of "Imitation" in Various-sized Groups and in Various-sized Volumes of Water.

	Aquaria		N. J. Pool		Florida Pool		
Number of fishes in groups	2	4	5	9	3	4	5
Total time of observation (in hours)	36	36	4½	1	1	1	8
No. fish in group rising	No. of rising fish in percent						
1	63	31	58	72	100	83	52
2	37	29	16	22	00	17	25
3	—	25	24	06	00	00	16
4	—	15	02	00	—	00	04
5	—	—	00	00	—	—	03
6	—	—	—	00	—	—	—
7	—	—	—	00	—	—	—
8	—	—	—	00	—	—	—
9	—	—	—	00	—	—	—

	Aquaria	N. J. Pool	Florida Pool
Area in sq. meters	0.196	15	115
Volume H_2O in liters	48	4,300	70,000
% of rises alone (weighted means)	47	61	60
% of group rises (weighted means)	53	39	40

TABLE X.

Chemical Analysis of Pools in New Jersey and Florida.

	Florida		New Jersey
Date (1940)	June 30	July 4	Aug. 28
Albuminoid ammonia (p.p.m. Nitrogen)	14.000	11.000	.200
Free Ammonia (p.p.m. Nitrogen)	21.000	15.000	.220
Nitrate (p.p.m. Nitrogen)	.25	.25	.25
Chlorine (p.p.m.)	17,400.	18,250.	3.6
Hardness (p.p.m. Calcium carbonate)	8,100	8,100	92
Alkalinity (p.p.m. Calcium carbonate)	106	116	78
PO_4 (p.p.m.)	1.2	1.7	—
SO_4 (p.p.m.)	1900	2010	16
Iron (p.p.m.)	.05	.10	.30
Turbidity	1	2	1
Color (p.p.m. Platinum)	220	200	10
Total solids (p.p.m.)	55430	46770	252

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EXPLANATION OF THE PLATES.

Plate I.

Respiratory behavior of tarpon under varying conditions. See text for explanation.

Fig. 1. A typical rise through a clean water surface. July 4, 1940.

Fig. 2. A typical rise through an algae-covered surface to left of center. June 26, 1940.

Fig. 3. Two sets of paired respiratory bubbles left entrained on algae-covered surface in lower left. June 25, 1940.

Plate II.

Fig. 4. Two tarpon rises at less than a second's interval. The first is represented by the rings of large diameter. Bubbles may be seen at its center from the fish which has already descended. The second, left of center, has not as yet started the Newton's ring formation. Drops are still falling from the splash formed as the fish broke the surface.

FIG. 1.

FIG. 2.

FIG. 3.

SOCIAL AND RESPIRATORY BEHAVIOR OF SMALL TARPON.

SOCIAL AND RESPIRATORY BEHAVIOR OF SMALL TARPON.

31.

New Observations on the Blood Group Factors in Simiidi and Cercopithecidae*†

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This paper will serve to describe some new findings with regard to the blood group factors in a lowland gorilla (*G. gorilla*), and in monkeys belonging to two species of macaque (*M. mulatta* and *M. irus*).

Since these findings are a direct outgrowth of the discovery that certain conclusions previously reported by one of us (Candela, In press) were incorrect, it may be profitable to recount the successive stages in the investigation in a more or less chronological order.

It has been known for some time that the blood group factors A, B and O, whose presence or absence determine the four blood groups in man, are to be found also in the blood of the anthropoid apes. This fact was first suggested by the finding of group A in one chimpanzee, whose blood was examined by v. Dungern & Hirszfeld (1910-11), and established by the systematic study of Landsteiner & Miller (1925), which revealed that the blood of anthropoids contained also the agglutinogen B, as well as A.

Since that time, the continuation of such investigations of the bloods of Simiidi and Hylobatidae has made it apparent that although all four groups are represented among the apes, each of the genera lacks at least one of the groups[1]. Thus, the chimpanzee, on the strength of about 100 individuals, has only groups O and A, while the orang-utan and the gibbon have only groups A, B and AB. Until recently, the gorilla, represented by only four individuals, was reported to have only group A[2].

This distribution of the blood group factors seemed to imply that the B factor was not present in either of the two African anthropoids. Since the gorilla and the chimpanzee are generally conceded to resemble man more closely than do the Asiatic apes, the apparent lack of the B factor was anomolous, and stimulated various theories postulating its independent origin in the Asiatic apes, and in African man.

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† A more extended report, including details of technique, will be published elsewhere. (Wiener, Candela & Goss, In preparation).

1 This observation applies also to certain of the races of man, the most outstanding examples being the American Indians, the Polynesians and the Australian natives.

2 Actually, as will be pointed out in a later paper (Wiener, Candela & Goss, In preparation), the results quoted on those four gorillas are entirely unreliable. The results reported by Landsteiner (1928) have been misquoted, since this investigator stated that he could not assign a definite group to the single gorilla which he examined. The results reported by Weinert on the remaining three gorillas have been shown by Dahr (1938) to be incorrect, since they are based on an invalid technique.

The importance of these questions to anthropology, and to the problem of human evolution, prompted one of us (C.) to attempt to determine the blood groups of the gorillas in the zoological parks of the United States, by means of tests upon their urines. Such tests are dependent upon the well-known fact that in man, at least, the group-specific substances responsible for the individual blood differences are present in water-soluble form in almost all the tissues and body secretions[3].

The results of the tests on the urines of seven gorillas, three chimpanzees and one orang-utan have been detailed in a previous publication (Candela, 1940). It is sufficient to state that two mountain gorillas (*G. berengei*) were found to belong to group A, three lowland gorillas (*G. gorilla*) to group B, while two other lowland gorillas appeared from the reactions to belong to group AB, and were so reported. Actually, the diagnoses upon these last two were erroneous, for reasons which will presently appear (v.i.).

The dependability of the results obtained by testing ape urine was demonstrated by control tests on twenty human beings, whose groups were determined by independent tests on urine and blood, with complete correspondence. In addition, the blood of the orang-utan, and that of one of the chimpanzees were obtained and tested, and here also the results of the urine tests were confirmed by the reactions of the blood.

Another reason for accepting the urine reactions at their face value lay in the fact that those urines which gave A or B reactions, did so at the same dilution levels found to be suitable for testing human urines. As for the AB reactions, in which the samples removed both the α and the β agglutinins from the test sera, at least one of these reactions, namely that obtained with the urine of the orang-utan, was confirmed by tests upon his blood. It therefore seemed plausible that the two other AB reactions, obtained from the urines of the two gorillas, Janet and Susie, respectively, were equally valid.

Tests upon the Blood of the Gorilla Janet.

An opportunity to check the accuracy of the urine tests on one of these two gorillas came with the transfer of Janet from the New York Zoological Society to the Laboratory of Physiology, The School of Medicine, Yale University, where certain studies were carried out under general anaesthesia.

Blood samples obtained at that time were examined by us, and the unexpected finding was made that the gorilla did not belong to group AB; in fact, it did not correspond exactly to any of the four human groups[4], although it resembled most closely blood of group B.

The serum contained α agglutinins of moderate strength[5], but no β agglutinins, and therefore corresponded with human group B serum. The erythrocytes were tested with anti-A and anti-B testing fluids, prepared from immune rabbit sera. No agglutination at all was obtained with the anti-A serum, and only very weak agglutination with the undiluted anti-B serum, although the latter gave distinct reactions with human B cells in dilutions as high as 1 to 32. Evidently, therefore, the gorilla blood contained an agglutinogen related to, but not identical with the human agglutinogen B. Thus, it is no longer accurate to state that the group factors in the blood of anthropoid apes are in all cases indistinguishable from those found in human blood.

Since the reactions of the gorilla's blood in anti-B serum were weak,

[3] This statement applies only to "secretors." In "non-secretors," who constitute about 20% of white populations, the group-specific substances are absent from the secretions, or present only in traces.

[4] In this respect, our results correspond with those of Landsteiner (footnote 2).

[5] These were accompanied by relatively weak anti-human species agglutinins.

they might have been open to question, in the absence of additional supporting evidence. Accordingly, advantage was taken of the death of the gorilla to study the group-specific substances in its organs. Aqueous extracts of the submaxillary gland were found to inhibit human A (anti-B) serum in relatively high dilutions, but to have no effect on group B (anti-A) sera. This confirmed the grouping of the gorilla's blood as "B-like, α".

The discrepancy between the results obtained from the tests upon the blood, and those previously obtained on the urine of this gorilla, necessitated the re-testing of the urine, not only of this gorilla, but also that of Susie, of the Cincinnati Zoological Society, who likewise had been thought to belong to group AB.

An interesting phenomenon was observed, in that while the undiluted or slightly diluted urines gave AB reactions, when they were diluted 1:6, they both gave B reactions[6], inhibiting the β agglutinin but not the α (Table 1). Since the inhibition of the α (anti-A) agglutinin was thus much weaker than that of the anti-B, the former cannot with any degree of certainty be attributed to the presence of group-specific substance A[7].

TABLE 1.

Results of the re-testing of specimens of urine from Janet and Susie, and three other apes.

Name	Species	Urine Dilution	Residual Agglutinins In: Group A serum	Group B serum
Janet	*G. gorilla*	1:3	—	—
Susie	*G. gorilla*	1:3	—	—
M'bongo	*G. berengei*	1:3	++++	—
Gargantua	*G. gorilla*	1:3	—	++++
Mike	*P. pygmaeus*	1:3	—	—
Janet	v.s.	1:6	—	++++
Susie	"	1:6	—	++++
M'bongo	"	1:6	++++	+++
Gargantua	"	1:6	+++	++++
Mike	"	1:6	++	++

Accordingly, it must be pointed out that the inaccuracy in reporting the groups of Janet and Susie as AB carries no implication as to the correctness of the conclusions arrived at with regard to the remaining nine apes in the series. This is particularly true since eight of these reacted as either group A or group B. With regard to the orang-utan, whose urine gave an AB reaction, his blood also gave an AB reaction, as has been already mentioned.

In summary, it may be said that, (1) The urines of the gorillas Janet and Susie had some adsorptive power for α as well as β, exceeding even the specific reactions of the urines of the remaining nine apes in the series and of the twenty human controls, but when tested at suitable dilution levels, they gave only distinct B reactions. (2) The blood cells obtained from Janet gave very weak reactions in anti-B serum, and none in anti-A serum, while the extract of the submaxillary gland gave a distinct B reaction. The serum of this gorilla contained α agglutinins but no β agglutinins. (3) Based on these new findings, it appears that of the seven gorillas tested to date, all five of the lowland species (*G. gorilla*) belong or are related to group B, while both of the mountain gorillas (*G. berengei*) belong or are related to group A.

[6] But at this dilution, the urines of the other apes did not afford clear reactions, nor did the human urines (Table 1).

[7] The phenomenon of the non-specific adsorption of both the α and the β agglutinins, with the production of false "AB" reactions, has been noted by one of us to occur also in the blood-grouping of human bones (Candela, In press).

TESTS UPON THE SECRETIONS AND BLOOD OF OLD-WORLD MONKEYS.

The interesting results obtained from the examination of the secretions, blood and tissues of the gorilla Janet suggested the performance of similar investigations upon monkeys.

The available information on the subject of the blood groups of monkeys is based on the examination of the blood alone. The data concerning old-world monkeys can be summarized as follows: (1) The erythrocytes of the Cercopithecidae are not agglutinated by anti-A or anti-B sera. (2) The sera of certain of these monkeys nevertheless contain anti-A or anti-B agglutinins. In the rhesus monkey (*M. mulatta*), anti-A agglutinins but not anti-B are regularly present in the serum; on the other hand, in *Cercopithecus*, anti-B is said to be present, but not anti-A. In baboons and other monkeys, one or the other agglutinin may be present, depending on the individual serum (Landsteiner, 1936; Thomsen & Kemp, 1930; Buchbinder, 1933).

From these observations, it has been concluded that the reciprocal or complementary arrangement of agglutinogens and agglutinins found in man and the anthropoid apes, does not hold true for monkeys. In man, and in the Simiidi and Hylobatidae, when the A factor is present alone in the blood cells, the serum contains agglutinin β, (or anti-B); when only the B factor is present, the serum contains α (anti-A); the absence of both factors from the blood cells is accompanied by the presence of both agglutinins in the serum; finally, when both factors A and B are present in the blood cells, neither iso-agglutinin is found in the serum.

The finding of a definite B factor in the salivary gland of the gorilla Janet, accompanied by distinct anti-A agglutinins in the serum, in the face of the extremely weak B reaction of the blood cells, suggested a new interpretation of the so-called blood group formula. It seemed possible that the lack of reciprocity between the reactions of the blood cells and those of the serum in monkeys might be reconciled by the results obtained from the examination of the tissues and secretions.

The first opportunity to test the validity of this idea arose when the death of a Java macaque (*M. irus*) made available for examination the sublingual gland, together with a block of tongue tissue[8]. The aqueous extract prepared from this material was found to inhibit, in high dilutions, human group A serum, but not to affect human group B serum, thus establishing the presence of group-specific substance B in the tissue extract.

Subsequently, the submaxillary gland and a sample of blood were obtained from a rhesus monkey (*M. mulatta*). The blood serum was found to contain a moderately strong α agglutinin, but the blood cells were not agglutinated by either anti-A or anti-B test sera. The extract prepared from the submaxillary gland inhibited group A serum, but not group B serum, thus yielding a definite B reaction, as anticipated from the presence of the α agglutinin but not the β agglutinin in the serum of the monkey.

In order to determine the presence of group-specific factors in the natural secretions of the macaques, specimens of urine from fifteen monkeys, identified only by numbers, were tested by one of us (C.). Four different kinds of reactions were obtained. In the first four samples, the tests all resulted in group B reactions. Of the remaining eleven, seven gave group A reactions. Three inhibited the A and B test sera equally; these could not be definitely interpreted, nor could a definite conclusion be reached upon the blood group of the monkey whose urine gave only a slight trace of inhibition of the α (anti-A) agglutinin.

The key list obtained after the completion of the tests disclosed the unexpected fact that, although all fifteen specimens of urine derived from macaques, the first four, which had given B reactions, had come from

[8] Except as otherwise indicated, all the material used in this study was personally collected and prepared by one of the authors (G.).

rhesus monkeys (*M. mulatta*), while the remaining eleven, which had yielded seven group A reactions, had been obtained from Java macaques (*M. irus*).

Samples of saliva, obtained from the same fifteen monkeys by means of cotton swabs applied to the floor of the mouth, were tested independently by another of us (W.). These afforded confirmation of the validity of the four B and seven A reactions, and revealed that three of the doubtful individuals belonged to group AB. The fourth, which had yielded an extremely weak A reaction, gave an equally weak A reaction with the saliva. The decision as to group is much easier to make in tests upon the saliva, since this secretion gives specific reactions which are much stronger than those of the urine. For this reason, the failure of the last mentioned specimen (Table 2, number 11), to give a distinct reaction even in tests upon the saliva, suggested the possibility of group O.

The final step in the clarification of the blood group characteristics of this series of monkeys consisted in the testing of their bloods. The results of these tests were in harmony with previous findings obtained with the blood of old-world monkeys, in that the cells could not be agglutinated, while the sera contained group-specific agglutinins.

However, the identification of A-like and B-like factors in the tissues and secretions now made it evident that a reciprocal relation exists in monkeys between group-specific substance in the secretions, and the agglutinins in the serum, just as it does in man and the anthropoid apes between the agglutinogens in the blood cells and the agglutinins in the serum. Every monkey whose tissues or secretions contained the B factor alone, had the α, or anti-A, agglutinin in its blood serum; those in which the A factor alone was found, possessed the β, or anti-B agglutinin in their sera; those three which had both the A and the B factors in their secretions, lacked both iso-agglutinins from their sera, while the one monkey whose secretions suggested group O, had both agglutinins α and β in its serum.

Familial Relationships.

After the completion of the blood group studies upon the monkeys, the family relationships of sixteen of them were clarified by reference to the records of the New York Zoological Society. These sixteen monkeys fall into three families, and their mutual relationships, indicated in Table 2 by the letters x, y and z, may be summarized as follows:

Family x: Java macaques. *Father*: monkey number 00; *mother*: monkey number 7; *children*: monkeys numbers 6 and 15. In this family, the father gave a group B reaction, while the mother and two children reacted as group AB.

Family y: Rhesus monkeys. *Father*: monkey number 2; *mother*: monkey number 1; *children*: monkeys numbers 3 and 4. All members of this family gave group B reactions.

Family z: Java macaques. *Father*: monkey number 5; *mother*: not available; *children*: almost certain, number 8; certain: monkeys numbers 9, 10, 11, 12, 13, and 14. All members of this family gave A reactions, with the exception of number 11, which gave reactions corresponding to group O.

The laws governing the inheritance of the blood group factors in man are, in essence, two: (1) Neither the A nor the B factor appears in an offspring unless it is present in one or the other parent. (2) A parent belonging to group O cannot have a child of group AB, and a parent belonging to group AB cannot have a child of group O.

Although the numbers of monkeys herein reported are too small to permit definite conclusions, it can be said that in these three families of macaques, at least, no exceptions were found to the laws which govern the transmission of blood group factors in humans.

TABLE 2.

Results of tests upon the secretions, tissues and bloods of a gorilla and seventeen macaques.

Name or number and family	Taxonomic name	Source	Reaction from urine*	Reaction from tissues or saliva*	Reaction from erythrocytes*	Group-specific agglutinin in serum	Indicated group
"Janet"	*G. gorilla*	(NYZS)	('AB')				
		(Yale)	(B)	B	B-like	∝	B
(x) 00. Java	*M. irus*	NYZS	not tested	B	not tested	not tested	B
0. Rhesus	*M. mulatta*	R.I.	not tested	B	'O'	∝	B
(y) 1. "	" "	NYZS	B	B	('O')†	(∝)†	B
(y) 2. "	" "	NYZS	B	B	('O')†	(∝)†	B
(y) 3. "	" "	NYZS	B	B	('O')†	(∝)†	B
(y) 4. "	" "	NYZS	B	B	('O')†	(∝)†	B
(z) 5. Java	*M. irus*	NYZS	A	A	'O'	β	A
(x) 6. "	" "	NYZS	O? AB?	AB	'O'	none	AB
(x) 7. "	" "	NYZS	O? AB?	AB	not tested	none	AB
(z) 8. "	" "	NYZS	A	A	'O'	β	A
(z) 9. "	" "	NYZS	A	A	'O'	β	A
(z) 10. "	" "	NYZS	A	A			A
(z) 11. "	" "	NYZS	A? O?	O? A?	'O'	∝, β	O?
(z) 12. "	" "	NYZS	A	A	'O'	β	A
(z) 13. "	" "	NYZS	A	A			A
(z) 14. "	" "	NYZS	A	A	'O'	β	A
(x) 15. "	" "	NYZS	O? AB?	AB	'O'	none	AB

Explanation of Symbols.

x, y, z: Family relationships.
NYZS: New York Zoological Society.
Yale: Laboratory of Physiology, Yale University.
R. I.: Rockefeller Institute for Medical Research.
* : Although the symbols A and B are used to represent the group-specific substances in the tissues and secretions, this is not intended to imply that these substances are completely identical with the corresponding factors in man.
()† : These bloods were not tested, since the findings on the blood of rhesus have been shown to be quite constant.

Summary of Results.

1. A gorilla whose blood group had previously been diagnosed as AB from tests upon the urine, was found actually to belong or be related to group B, as a result of tests upon the blood and tissues. The apparent discrepancy was due to the reactivity of the urine for anti-A as well as anti-B sera, at dilution levels suitable for other specimens; in higher dilutions, the urine gave distinct B reactions. The reactions obtained by tests upon the blood serum and upon an extract of the gorilla's submaxillary gland closely paralleled those of a human group B individual. However, the erythrocytes were only feebly agglutinated by anti-B sera, indicated that the agglutinogen present in the blood was similar to, but not identical with the human B agglutinogen.

Of a total of seven gorillas tested, the revised results reveal that all five of the lowland gorillas (*G. gorilla*) belong or are related to group B, while both of the mountain gorillas (*G. berengei*) belong or are related to group A.

2. Examination of the blood of one rhesus monkey (*M. mulatta*) confirmed the well-known fact that the cells of this primate are not agglutinated by anti-A and anti-B immune testing fluids, while the blood serum contains α (anti-A) agglutinin, but no β (anti-B) agglutinin.

3. The examination of the secretions or the tissues of five rhesus monkeys (including the one mentioned above) elicited the significant fact that a B-like factor, which had been thought to be entirely absent, is actually present, being demonstrable, not in the erythrocytes, but in the tissues and secretions.

4. The Java macaque (*M. irus*) was found to differ in its serology from rhesus, who belong exclusively to group B, in that reactions were obtained corresponding to groups A and AB, as well as group B. In seven of the twelve Java macaques examined the secretions gave a group A reaction, while the serum contained the β or anti-B agglutinin. The eighth individual was found to possess a B-like factor in his tissues; blood from this individual was not available for testing. Of the remaining four, three reacted as AB, in that their secretions inhibited both the α and the β agglutinins, while their sera did not contain either anti-A or anti-B agglutinins. The twelfth Java macaque gave very faint group A reactions from his urine and saliva, but was found to possess both the anti-A and anti-B agglutinins in his blood serum. Although these findings would seem to suggest a diagnosis of group O, further study is necessary for a definite decision.

The finding of an A-like factor in seven Java macaques is believed to be the first demonstration of the presence of the A factor in any monkey.

5. A correlation of the results of the blood group tests with the familial relationships of the three families of macaques discloses no exceptions to the rules which govern the heredity of the blood group factors in man.

Conclusions.

The results of our investigations upon the blood group characteristics of a lowland gorilla, five rhesus monkeys and twelve Java macaques permit certain conclusions to be drawn. These may have new implications for the general problem of the blood groups, and for the questions of the serological interrelationships of the primates.

The findings with respect to the secretions, tissues and blood of the gorilla provide an exception to the rule which holds for the other anthropoid apes, whose bloods gave reactions indistinguishable from those of man.

It is believed that our results have established for the first time the presence, in the tissues and secretions, of both A-like and B-like factors in the two varities of macaques which were studied. These group-specific

factors are in each case accompanied by complementary agglutinins in the serum. Thus, a reciprocal arrangement of agglutinogen and agglutinin previously found only in man and the great apes, is now shown to hold true also in monkeys.

The apparent lack heretofore of such reciprocity was due to the fact that blood group investigations on monkeys have been confined to tests upon their bloods. The reactions obtainable from the secretions and tissues should constitute a valuable implement for future studies in the field of primate blood groups.

There is a suggestion in our results that certain blood group formulae may be distinctive for some of the species of anthropoids and monkeys. The large numbers of studies previously made on the rhesus monkey, reinterpreted in the light of our findings, justify the belief that all members of this species are related to group B. In the instance of the Java macaque, however, even the few herein reported suffice to show that they possess both the A and the B factors. Among gorillas, results from only seven individuals remain available at the present writing, since the four previously reported must now be discounted. These are insufficient to permit deductions; still it may be significant that all five of the lowland gorillas are now known to be similar to group B, and both individuals of the mountain species to group A.

It is significant that the only species of primates in which group O has been found are man and the chimpanzee[9,10]. This suggests the possibility that the O property may have arisen by mutation from either the A or the B factor (probably the former), rather than the reverse mechanism, accepted by some writers, that A and B represent mutations from an original background of group O.

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[9] The O property is not common even in the chimpanzee, since of the one hundred individuals tested, only twelve have been reported to be group O.

[10] Although one of the Java macaques which we tested (number 11) appears to resemble a group O individual, some features of the results indicate caution in the acceptance of such a diagnosis. Further study of this monkey may reveal it to be a non-secretor, with atypical agglutinins (see footnote 3).

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32.

Muscle Dystrophy in Tree Kangaroos Associated with Feeding of Cod Liver Oil and Its Response to Alpha-Tocopherol.

LEONARD J. GOSS.

It is the purpose of this paper to report muscle dystrophy observed in tree kangaroos that conforms to that first produced artificially by Goettsch & Pappenheimer in Guinea pigs and rabbits maintained on a diet deficient in vitamin E. Similar lesions have been observed in rats by Evans & Lipschutz, who thought it to be of nervous origin. Olcott however definitely associated it with disease of skeletal muscles. A similar condition has also been seen in lambs and is known as "stiff lamb" disease.

The deleterious effect of oxidation on Vitamin E has long been known. It has also been shown that Vitamin E is affected by oxidation, when in association with such oxidizing agents as rancid oil. Madsen, McCay & Maynard showed that cotton seed oil containing a concentrate of Vitamins A and D in place of cod liver oil afforded a high degree of protection against muscular dystrophy in Herbivora and that one of the causative factors of the disease was in the saponifiable fraction of cod liver oil. McCay, Paul & Maynard prevented muscle lesions in Guinea pigs by using hydrogenerated cod liver oil in place of natural cod liver oil. In dealing with encephalomalacia of chicks, Pappenheimer & Goettsch showed that hydrogenation greatly stabilizes fats that ordinarily readily become rancid. With these facts in mind we wish to report the occurrence of muscle dystrophy in tree kangaroos, its response to Alpha-Tocopherol treatment and its occurrence when oils were added to the diet.

In June, 1938, four tree kangaroos were received at the New York Zoological Park, indirectly from Australia. From June, 1938, until April 20, 1939, these animals were each maintained in the Park on an average daily ration of 2 small raw potatoes, 1 raw apple, ¼ head of lettuce, ½ slice whole wheat bread, 1 medium-sized raw carrot and a small quantity of hay. The hay varied from alfalfa to mixed timothy and clover. On June 20, 1939, a fish oil mixture containing 3,400 units of Vitamin A and 660 units of Vitamin D per gram was added to the ration at the rate of 1 teaspoonful per animal per day. This oil mixture had been stored in a refrigerator since February, 1939, in a 29-gallon metal drum which was opened periodically to withdraw oil through a petcock.

On June 10, 1939, kangaroo No. 1 showed symptoms of stiffness, at which time the fish oil mixture was omitted from the balance of the usual ration. For a period of six weeks thereafter she was taken outdoors each day, weather permitting, and allowed to nibble on fresh green grass. Improvement was gradual and after six weeks of such treatment the symptoms of muscular stiffness had disappeared.

July 20, 1939, animal No. 2 developed symptoms of stiffness which became progressively worse and resulted in death in 2 days.

On September 22, 1939, animal No. 3 became stiff and died in 7 days.

The fish oil was removed from the diet when symptoms first appeared. All muscles, including the tongue, were severely affected.

On October 27, 1939, animal No. 4 became stiff and died in 6 days. All the dead animals showed extensive gross and microscopic lesions of muscle dystrophy, characterized by edema, opaqueness, a yellowish white coloration and in the later stages a gritty appearance. All voluntary muscles, including the tongue, were affected. The microscopic changes consisted of necrosis of the fibres, loss of fibrillar structure and calcium impregnation associated with varying stages of inflammatory reaction and myocytic regeneration.

Animal No. 1, which became stiff on June 10, 1939, was never put back on the fish oil diet but rather maintained on her original diet as outlined above. On January 19, 1940, she again developed typical symptoms of muscle dystrophy, this time without having had any oil. On January 20 the symptoms had become more marked and 25 milligrams of Alpha-Tocopherol were given by mouth. Three days later the symptoms had disappeared completely. This animal died July 3, 1940, of actinomycosis without having had a relapse since the administration of Alpha-Tocopherol. The second attack of muscular degeneration in the first animal affected is difficult to explain in the absence of oil in the diet. We must, however, assume that the regular ration bordered on deficiency in Vitamin E. This would account both for the occurrence of muscle degeneration in the animals when the oil was added to the diet and for the second attack in the one animal.

The results obtained when a fish oil mixture was included in the diet indicate that the oil itself has some action in producing muscular degeneration or that it inhibits the action of Vitamin E in preventing the disease.

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33.

Mortality Statistics for Specimens in the New York Aquarium, 1939.

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Pathologist

(Plates I-III).

Introduction.

Approximately 1,600 specimens which died in the New York Aquarium during 1939 were examined to determine the cause of death. These are listed in Tables I to IV. A large number of specimens, especially fishes, which are being collected more or less continually for food and which also become part of the exhibition, are not included in this report. Such forms represent about 30% of the total population as given in the annual census. Also not included are those specimens which died immediately after their arrival; when large collections are made, from 20% to 30% usually survive long enough to become part of the Aquarium's exhibited population. However, in smaller, more selected collections, as much as 90% or more may survive. It should be remembered that aquatic species of animals, especially fishes, are difficult to handle and that those factors which tend to weaken them, *e.g.*, netting, transportation, change of water, also tend to lower their resistance to infective agents.

It is now pretty well established that host specificity among fishes and their parasites is the exception rather than the rule. One thing is certain—that under aquarium conditions such a relationship, if it exists at all, soon ceases to be, and may even take on an epidemic form, as in several cases reported here. In addition, it is known that infective agents tend to become more virulent in their effects when established on "abnormal" hosts.

Insofar as aquatic animals are concerned, the most virulent of the parasitic diseases are usually caused by external parasites, either protozoan or metazoan (flukes and copepods) living for the most part on the skin, eyes and gills.

It is very difficult in many instances to separate the primary from the secondary causes of death. For example, the primary cause which lowers the resistance of a given specimen may be a physical (such as fighting), chemical (changes in the water), or physiological (humoral or nutritional) one. If any of these adverse factors is sustained long enough, death follows; infective agents in such an instance may be but a secondary cause which only speeds up the demise.

The histo-pathology of the lesions produced by the various diseases has been, or will be, reported from time to time and therefore is not included in this report.

The writer wishes to express his thanks to Mr. James Atz for his assistance in the preparation of this paper.

CAUSES OF DEATH OF MARINE FISHES. TABLE I.

The great majority of the marine fishes were kept in a closed circulating system; some of the local species, however, were maintained in water pumped from the adjoining bay. This is the principal reason why more than half of the deaths of marine fishes resulted from infectious and parasitic diseases (Table V). The largest number of these was due to *Oodinium ocellatum*. This protozoan parasite was first observed in the New York Aquarium in 1935 (Nigrelli, 1936). At that time the fishes harboring it were indigenous to Sand Hook Bay. During 1939 the infection appeared on fishes collected from Florida, especially in those forms belonging to the families Lutianidae and Haemulidae. It is interesting to note that *Oodinium ocellatum* was first described from West Indian fishes kept in the London Aquarium. We have had an opportunity to study the organism from fishes of both regions and have come to the conclusion that the parasite is the same.

Among Sandy Hook Bay fishes a new protozoan parasite made its appearance in 1939. The life-history studies of this *Trichodina* were reported by Padnos (1939a and b). The parasite is found in large numbers on the gills of the common puffer and to a lesser extent on other species. The incidence of infection in puffers from Sandy Hook Bay is very high and studies indicate that these fish may be a potential source of infection of this and other parasitic diseases.

In previous years, *Epibdella melleni*, a monogenetic trematode, was the major cause of deaths of marine fishes, especially those belonging to the spiny-rayed group (Nigrelli & Breder, 1934). In 1939 most of the fishes infected belonged to the families Lutianidae, Haemulidae and Chaetodontidae. The latter includes some of the handsomest of all West Indian fishes, but is most susceptible to this trematode. Various techniques, however, are employed to keep this parasite under control, as well as other monogenetic trematodes of less importance, such as *Microcotyle* and *Diplectanus*. The life-history of *Microcotyle* and *Diplectanus* is being studied by Paul (1939).

One of the most interesting, but less devastating, of infectious diseases is lymphocystis (Nigrelli & Smith, 1939). This condition has been attributed to a virus causing tremendous hypertrophy of cells of connective tissue origin. The condition is usually limited to such cells in the skin and fins, but in more severe instances hypertrophied cells have been found in the spleen, gastro-intestinal tract and ovaries. Insofar as could be determined, no cellular disease of this type has been reported for man.

The largest number of mortalities attributed to parasitic and infectious diseases in marine fishes occurred during the months of July and August (Table VI), soon after the arrival of a large collection from Florida. As was stated in the Annual Report of the Zoological Society (Nigrelli, 1940a), the rate of mortality is far greater in recently arrived specimens.

One disease about which we as yet know nothing, although it was sporadic in occurrence, involves a peculiar ulceration of the skin around the mouth and the fins. Plate I, Figs. 1 & 2, shows a queen triggerfish with this affliction. The condition is first made evident by sores around the mouth, which continue to spread, resulting eventually in a sloughing off of tissues in this region; later the fins become involved, there being an intense inflammation of the skin at their bases. Biopsied and autopsied material failed to reveal the presence of a causative agent. The internal organs were normal to all appearances, but in most cases the optic nerves were inflamed and the optic muscles completely atrophied.

About 20% of the deaths of marine fishes resulted from non-infectious diseases, with a variety of causes and occuring throughout the year. Most of these diseases affected fishes which had been on exhibition for more than one year, and are of the type, with rare exceptions, that normally would be expected among any animal population of similar proportions and under

conditions of confinement. Some of these may be of parasitic origin, although no causative agents have been recovered; others may be entirely humoral or nutritional. The above remarks also hold for those non-infectious deaths among the other two groups of fishes.

Fishes are susceptible to relatively slight adverse changes in the physical, chemical and thermal conditions of their environment—some more so than others, but all to a certain degree. Therefore it is not surprising to find that a number of specimens succumbed as a result of such changes. The Elasmobranchs are particularly sensitive to changes in specific gravity, for example.

Causes of Deaths of Temperate Fresh-water Fishes. Table II.

A lower mortality rate occurred among the temperate fresh-water fishes. This may be attributed for the most part to the fact that these fishes were kept in an open circulation for most of the year. Any infection on one specimen was usually limited to that individual or perhaps its tank-mates. The present closed circulation was put into operation in October, 1939. However, the increase in mortality during the last two months of the year resulted from the influx of a large collection from Illinois, rather than the effects of the closed circulation (Table VI).

The largest number of deaths among this group was caused by *Ichthyophthirius multifiliis,* a well known and at times very virulent protozoan parasite. More than three-quarters of the deaths reported from this cause, however, occurred in one species of catfish. These fish were from one to two inches long and were confined in a single tank.

Saprolegnia only attacks fresh-water fishes which have been injured either mechanically or by parasites. Handling thus presents a constant hazard, since spores of this fungus are omnipresent.

Among helminth infections, some losses were attributed to worms belonging to the monogenetic trematode group referred to as Gyrodactyloides. These are skin and gill parasites, and a large number of species have been reported from fresh-water fishes. They constitute the most dreaded parasite in aquarium and hatchery management, often causing the loss of great numbers of specimens.

The disease referred to as Myxomata is very interesting and in all probability of parasitic origin. The general effects of any of the external parasites is to produce an irritation of the skin which results in an excessive production of mucus, the most important protective mechanism of fishes. Sometimes a translucent, soft growth remains, covering the whole fish or parts of it. This growth is microscopically seen to be composed of stellate-shaped connective tissue cells. One difference between this type of tumor and those of similar nature reported for man and other mammals is that the myxomata in the latter are richly supplied with capillaries.

The number of deaths recorded under Temperature is almost entirely accounted for by losses incurred among the trouts during the summer months. Mortalities recorded under Chemical Poisoning refer to a single species. A tank of muskellunge on open circulation was treated for a slight infection of *Ichthyophthirius* with a protein—silver salt, a compound continually used for such purposes. A chemical interaction between this chemical and the chlorine in the water at that time resulted in the formation of silver chloride, a highly toxic substance to fishes.

Causes of Death of Fresh-water Tropical Fishes. Table III.

These comprise some of the smallest of fishes, and it is consequently very difficult to perform adequate autopsy. For this reason, many deaths resulting from undetermined causes are listed here.

It is known among ecologists, aquarists and tropical fish fanciers that fishes living in small standing bodies of water alter the chemical content of their environment, apparently not only making it more suitable for themselves, but sometimes rendering it completely unsuitable for even rather closely related species. This has been called water conditioning. It is a very important factor in the maintenance of tropical fish, and a very large portion of the 23% of deaths recorded under Acclimatization resulted from these small fishes being unable to adjust themselves satisfactorily to a new aquatic environment. Just what this conditioning is has so far evaded successful analysis. Evidence indicates that some specific animal proteins may be involved.

Because these fishes are kept in completely separated tanks, the incidence of infectious disease is practically negligible.

Causes of Death of Reptiles. Table IV.

The largest number of deaths among reptiles was attributed to a general enteritis. Just what was producing this condition in the Aquarium specimens has not been determined. Since no parasitic infection was evident, it is altogether possible that the condition may be nutritional.

The most interesting of reptilian diseases so far studied is the one developed by large alligators, previously reported as fatty degeneration (Nigrelli, 1940a). Large deposits of encapsulated fatty substance may be found just beneath the skin; between layers of muscles (Plate III, Fig. 7) and possibly extending into muscular tissues; between the muscles and the peritoneum, lying just outside the latter; and also inside the peritoneal cavity. There are indications that organs may be involved, too. Animals suffering from this disease may lie in the pools for weeks, refusing all food. Just before death they may have one or more severe hemorrhages through the snout, mouth or anus.

Causes of Death of Invertebrates. Table IV.

Although the great majority of invertebrates on exhibition were not autopsied, it is definitely known that these creatures are extremely sensitive to changes in the chemical composition of the water about them, Table V. Thus it is believed that the small sample autopsied does not at all exaggerate the importance of this factor as a cause of death.

Table I.

Causes of Mortality in Marine Fishes.

Disease	Fish	No. Deaths
Oodinium ocellatum Brown 32.6%[1]	Holocentridae	
	Holocentrus ascensionis (Osbeck), Squirrelfish	5
	Cheilodipteridae	
	Apogon maculatus (Poey), Spotted Cardinal Fish	5
	Serranidae	
	Centropristus striatus (L.), Sea Bass	9
	Epinephelus adscensionis (Osheck),	2
	Rock Hind	4
	Epinephelus morio (C. & V.), Red Grouper	1
	Petrometopon cruentatus (Lac.), Graysby	6

[1] Percentage of total number of recorded deaths.

Rypticus saponaceus (B. & S.), Soapfish	1
Lutianidae	
Lutianus analis (C. & V.), Muttonfish	2
Lutianus apodus (Walbaum), Schoolmaster	7
Lutianus griseus (L.), Gray Snapper	4
Lutianus jocu (B. & S.), Dog Snapper	2
Lutianus synagris (L.), Spot Snapper	9
Ocyurus chrysurus (Bloch), Yellowtail	17
Haemulidae	
Anistoremus virginicus (L.), Porkfish	40
Haemulon albium C. & V., Margate Fish	1
Haemulon flavolineatum (Desmarest), Yellow Grunt	15
Haemulon macrostomum Gthr., Gray Grunt	5
Haemulon plumieri (Lac.), White Grunt	8
Haemulon sciurus (Shaw), Blue-striped Grunt	18
Haemulon sp., Iron Grunt	1
Sciaenidae	
Eques acuminatus (B. & S.), Cubbyu	4
Menticirrhus saxatilis (B. & S.), Northern Kingfish	6
Pomacentridae	
Abudefduf saxatilis (L.), Sergeant-major	2
Dascyllus aruanus (L.), Jesuite	8
Scaridae	
Scarus caeruleus (Bloch), Blue Parrotfish	10
Chaetodontidae	
Angelichthys isabelita Jordan & Ritter, Blue Angelfish	4
Pomacanthus arcuatus (L.), Black Angelfish	23
Pomacanthus paru (Bloch), French Angelfish	12
Acanthyridae	
Acanthurus caeruleus B. & S., Blue Tang	6
Acanthurus hepatus (L.), Doctorfish	2
Balistidae	
Balistes vetula L., Queen Triggerfish	4
Ostraciidae	
Lactophrys trigonus (L.), Common Trunkfish	9
Tetraodontidae	
Spheroides maculatus (B. & S.), Puffer	23
Diodontidae	
Chilomycterus schoepfii (Walbaum), Spiny Boxfish	17
Didon hystrix L., Porcupine Fish	2
Triglidae	
Prionotus carolinus (L.), Carolina Sea Robin	8
Prionotus sp., Blue-winged Sea Robin	2

Trichodina sp. 10.3%	Carangidae	
	Caranx crysos (Mitch.), Hard-tailed Jack	9
	Serranidae	
	Centropristus striatus (L.), Sea Bass	5
	Roccus lineatus (Bloch), Striped Bass	3
	Sparidae	
	Stenotomus chrysops (L.), Porgy	2
	Sciaenidae	
	Menticirrhus saxatilis (B. & S.) Northern Kingfish	7
	Tetraodontidae	
	Spheroides maculatus (B. & S.), Puffer	43
	Diodontidae	
	Chilomycterus schoepfii (Walbaum), Spiny Boxfish	12
	Triglidae	
	Prionotus carolinus (L.), Carolina Sea Robin	6
	Prionotus evolans (L.), Striped Sea Robin	8
Epibdella melleni MacCallum 17.9%	Holocentridae	
	Holocentrus ascensionis (Osbeck), Squirrelfish	2
	Carangidae	
	Vomer setapinnis (Mitch.), Moonfish	4
	Serranidae	
	Cephalopholis fulvus (L.), Coney	1
	Dermatolepis marmoratus Osburn & Mobray, Marbled Grouper	1
	Epinephelus adscensionis (Osbeck), Rock Hind	1
	Mycteroperca interstitialis (Poey), Princess Rockfish	2
	Lobotidae	
	Lobotes surinamensis (Bloch), Tripletail	1
	Lutianidae	
	Lutianus analis (C. & V.), Muttonfish	5
	Lutianus apodus (Walbaum), Schoolmaster	1
	Lutianus griseus (L.), Gray Snapper	1
	Lutianus jocu (B. & S.), Dog Snapper	1
	Lutianus synagris (L.), Spot Snapper	5
	Ocyurus chrysurus (Bloch), Yellowtail	1
	Haemulidae	
	Anistoremus virginicus (L.), Porkfish	26
	Haemulon flavolineatum (Demarest), Yellow Grunt	2
	Haemulon macrostomum Gthr., Gray Grunt	10
	Haemulon plumieri (Lac.), White Grunt	1
	Haemulon sciurus (Shaw), Blue-striped Grunt	3

	Sparidae	
	Salema rhomboidalis (L.), Salema	1
	Sciaenidae	
	Pogonias cromis (L.), Sea Drum	1
	Labridae	
	Bodianus rufa (L.), Spanish Hogfish	5
	Julis pavo (C. & V.), Swallow-tailed Wrasse	3
	Lachnolaimus maximus (Walbaum), Hogfish	16
	Trechocopus scrofa (C. & V.), Pink Wrasse	3
	Ephippidae	
	Chaetodipterus faber (Broussonet), Spadefish	5
	Chaetodontidae	
	Angelichthys ciliaris (L.), Queen Angelfish	4
	Angelichthys isabelita Jordan & Ritter, Blue Angelfish	29
	Angelichthys townsendi Nichols & Mowbray, Townsend's Angelfish	1
	Chaetodon capistratus L., Four-eyed Butterflyfish	5
	Chaetodon collaris Bloch, Lattice-work Fish	3
	Chaetodon ocellatus Bloch, Common Butterflyfish	3
	Heniochus acuminatus (L.), Long-finned Butterflyfish	1
	Platax sp., Sea Bat	1
	Pomacanthus arcuatus (L.), Black Angelfish	7
	Acanthyridae	
	Acanthurus hepatus (L.), Doctorfish	3
	Balistidae	
	Balistes carolinensis Gmelin, Common Triggerfish	2
	Balistes vetula L., Queen Triggerfish	1
	Canthidermis sabaco Poey, Ocean Triggerfish	4
Microcotyle sp. .76%	Chaetodotidae	
	Chaetodon capistratus L., Four-eyed Butterflyfish	2
	Chaetodon collaris Bloch, Lattice-work Fish	3
	Chaetodon pictus Forskål, Striped Butterflyfish	1
	Holocanthus tricolor (Bloch), Rock Beauty	1
Diplectanus sp. .54%	Pomacentridae	
	Abudefduf saxatilis (L.), Sergeant-major	1
	Tetraodontidae	
	Tetraodon fluviatilis (Buch.), Fresh-water Puffer	4

Lymphocystis .43%	Pomacentridae	
	Amphiprion percula (Lac.), Clownfish	1
	Chaetodontidae	
	Angelichthys isabelita Jordan & Ritter, Blue Angelfish	2
	Monacanthidae	
	Ceratacanthus schoepfii (Walbaum) Orange Filefish	1
Ulceration of skin and fins .54%	Kyphosidae	
	Kyphosus sectatrix (L.), Bermuda Chub	2
	Ephippidae	
	Chaetodipterus faber (Broussonet), Spadefish	1
	Balistidae	
	Balistes vetula L., Queen Triggerfish	2
Trematode enteritis 1.30%	Holocentridae	
	Holocentrus ascensionis (Osbeck), Squirrelfish	2
	Carangidae	
	Caranx hippos (L.), Common Jack	1
	Serranidae	
	Centropristus striatus (L.), Sea Bass	1
	Epinephelus morio (C. & V.), Red Grouper	1
	Mycteroperca bonaci (Poey), Black Grouper	2
	Roccus lineatus (Bloch), Striped Bass	1
	Lutianidae	
	Ocyurus chrysurus (Bloch), Yellowtail	2
	Scorpaenidae	
	Scorpaena madurensis (C. & V.), Madeira Scorpionfish	2
Cestode enteritis .65%	Galeidae	
	Carcharhinus milberti Müller & Henle, Ground Shark	2
	Acipenseridae	
	Acipenser oxyrhynchus Mitch., Common Sturgeon	2
	Carangidae	
	Caranx crysos (Mitch.), Hard-tailed Jack	1
	Triglidae	
	Prionotus carolinus (L.), Carolina Sea Robin	1
Protozoan enteritis .11%	Diodontidae	
	Chilomycterus schoepfii (Walbaum), Spiny Boxfish	1
Gastritis 2.49%	Ginglymostomidae	
	Ginglymostoma cirratum (Bonnaterre), Nurse Shark	1

	Acipenseridae	
	Acipenser oxyrhynchus Mitch., Common Sturgeon	4
	Serranidae	
	Centropristus striatus (L.), Sea Bass	2
	Roccus lineatus (Bloch), Striped Bass	1
	Sciaenidae	
	Bairdella chrysura (Lac.), Silver Perch	4
	Leiostomus xanthurus Lac., Spot	4
	Micropogon undulatus (L.), Croaker	1
	Sciaenops ocellatus (L.), Channel Bass	6
Biliary cirrhosis .22%	Siluridae	
	Galeichthys felis (L.), Sea Catfish	1
	Ephippidae	
	Chaetodipterus faber (Broussonet), Spadefish	1
Fatty degeneration of liver .22%	Serranidae	
	Centropristus striatus (L.), Sea Bass	2
Hepatitis, nematode infection .11%	Gadidae	
	Urophycis chuss (Walbaum), Squirrel Ling	1
Renal calculi .11%	Serranidae	
	Mycteroperca bonaci (Poey), Black Grouper	1
Kidney degeneration .54%	Serranidae	
	Mycteroperca bonaci (Poey), Black Grouper	1
	Ephippidae	
	Chaetodipterus faber (Broussonet), Spadefish	1
	Batrachoididae	
	Opsanus tau (L.), Toadfish	3
Ovarian degeneration .87%	Carchariidae	
	Carcharias littoralis (Mitch.), Sand Shark	1
	Aëtobatidae	
	Rhinoptera quadriloba (Le S.), Cow-nosed Ray	1
	Acipenseridae	
	Acipenser oxyrhynchus Mitch., Common Sturgeon	3
	Serranidae	
	Mycteroperca bonaci (Poey), Black Grouper	3
Fatty degeneration, general .87%	Muraenidae	
	Gymnothorax funebris Ranzani, Green Moray	1

Fatty degeneration, general (continued)	Serranidae	
	Epinephelus striatus (Bloch), Nassau Grouper	3
	Mycteroperca bonaci (Poey), Black Grouper	2
	Lutianidae	
	Lutianus griseus (L.), Gray Snapper	2
Swim-bladder disorder 2.27%	Gadidae	
	Gadus callarias L., Cod	21
Gas aneurisym .54%	Sparidae	
	Stenotomus chrysops (L.), Porgy	1
	Sciaenidae	
	Menticirrhus saxatilis (B. & S.), Northern Kingfish	1
	Diodontidae	
	Chilomycterus schoepfii (Walbaum), Spiny Boxfish	2
	Triglidae	
	Prionotus carolinus (L.), Carolina Sea Robin	1
Malnutrition 4.65%	Syngnathidae	
	Hippocampus hudsonius ssp. De Kay, Seahorse	16
	Hippocampus sp., Long-nosed Seahorse	7
	Scaridae	
	Pseudoscarus guacamaia (Cuv.), Rainbow Parrotfish	8
	Scarus caeruleus (Bloch), Blue Parrotfish	9
	Monacanthidae	
	Ceratacanthus schoepfii (Walbaum), Orange Filefish	3
Trauma of eyes .43%	Ephippidae	
	Chaetodipterus faber (Broussonet), Spadefish	2
	Acanthyridae	
	Acanthurus hepatus (L.), Doctorfish	2
Exophthalmos .32%	Serranidae	
	Centropristus striatus (L.), Sea Bass	3
Tumor of thyroid 1.08%	Cyprinodontidae	
	Cyprinodon variegatus Lac., Sheepshead Minnow	10
Senility? .97%	Siluridae	
	Galeichthys felis (L.), Sea Catfish	2
	Muraenidae	
	Gymnothorax funebris Ranzani, Green Moray	2
	Carangidae	
	Trachinotus glaucus (Bloch), Palometa	1

	Labridae	
	Halichaeres radiatus (L.), Pudding-wife	1
	Thalassoma bifasciatus (Bloch), Bluehead	1
	Cichlidae	
	Tilapia mossambica Peters	1
	Diodontidae	
	Diodon hystrix L., Porcupine Fish	1
Fractured skull .32%	Galeidae	
	Mustelus canis (Mitch.), Smooth Dogfish	2
	Sciaenidae	
	Cynoscion regalis (B. & S.), Weakfish	1
Eaten by tankmates .22%	Pomacentridae	
	Pomacentrus albofasciatus Schl., Striped Pomacentrus	2
Jumped from tank .43%	Mugilidae	
	Mugil cephalus L., Mullet	1
	Ostraciidae	
	Ostracion cornutus (L.), East Indian Cowfish	1
	Scorpaenidae	
	Pterois volitans (Bennett), Zebra Fish	2
Fighting .54%	Muraenidae	
	Gymnothorax funebris Ranzani, Green Moray	1
	Gymnothorax moringa (Cuv.), Spotted Moray	1
	Pomacentridae	
	Eupomacentrus leucostictus (Müller & Troschel), Beau Gregory	3
Handling 1.41%	Syngnathidae	
	Hippocampus h. hudsonius De Kay, Northern Seahorse	11
	Ephippidae	
	Chaetodipterus faber (Broussonet), Spadefish	2
Destroyed .54%	Holocentridae	
	Holocentrus ascensionis (Osbeck), Squirrelfish	5
Water chemistry 11.3%	Ginglymostomidae	
	Ginglymostoma cirratum (Bonnaterre), Nurse Shark	2
	Galeidae	
	Carcharhinus milberti Müller & Henle, Ground Shark	1
	Mustelus canis (Mitch.), Smooth Dogfish	8
	Carchariidae	
	Carcharias littoralis (Mitch.), Sand Shark	1

Water chemistry (continued)	Rajidae	
	Raja spp., Rays	10
	Dasyatidae	
	Dasyatis centrura (Mitch.), Stingray	5
	Aëtobatidae	
	Rhinoptera quadriloba (Le S.), Cow-nosed Ray	10
	Muraenidae	
	Gymnothorax funebris Ranzani, Green Moray	1
	Syngnathidae	
	Hippocampus h. hudsonius De Kay, Northern Seahorse	30
	Carangidae	
	Seriola zonata (Mitch.), Rudderfish	14
	Serranidae	
	Centropristus striatus (L.), Sea Bass	20
	Roccus lineatus (Bloch), Striped Bass	2
Unknown 4.44%	Megalopidae	
	Tarpon atlanticus (C. & V.), Tarpon	1
	Anguillidae	
	Anguilla rostrata (Le S.), Common Eel	1
	Mugilidae	
	Mugil cephalus L., Mullet	3
	Pleuronectidae	
	Paralichthys dentatus (L.), Fluke	3
	Pseudopleuronectes americanus (Walbaum), Winter Flounder	8
	Soleidae	
	Achirus fasciatus Lac., Hog Choker	3
	Cheilodipteridae	
	Apogon maculatus (Poey), Spotted Cardinal Fish	3
	Sciaenidae	
	Eques acuminatus (B. & S.), Cubbyu	4
	Menticirrhus saxatilis (B. & S.), Northern Kingfish	4
	Pomacentridae	
	Amphiprion melanopus Blkr., Anemone Fish	3
	Ostraciidae	
	Lactophrys trigonus (L.), Common Trunkfish	1
	Tetraodontidae	
	Tetraodon sp., Pacific Puffer	1
	Scorpaenidae	
	Scorpaena madurensis (C. & V.), Madeira Scorpion Fish	2
	Echeneididae	
	Echeneis naucrates L., Sharksucker	4

TABLE II.

Causes of Mortality in Temperate Fresh-water Fishes.

DISEASE	FISH	NO. DEATHS
Saprolegnia sp. 6.66%[1]	Catostomidae	
	Ictiobus bubalis (Raf.), Buffalo Fish	7
	Moxostoma aureoleum (Le S.), Redhorse Sucker	1
	Siluridae	
	Ameiurus nebulosus (Le S.), Common Bullhead	5
	Ictalurus punctatus (Raf.), Channel Cat	1
Ichthyophthirius multifiliis Fouquet 45.3%	Salmonidae	
	Salmo irideus Gibbons, Rainbow Trout	1
	Cyprinidae	
	Campostoma anomalum (Raf.), Stone-roller Minnow	2
	Ericymba buccata Cope, Silver-mouthed Minnow	2
	Hybognathus sp.	4
	Pimephales promelas Raf., Fat-headed Minnow	1
	Semotilus atromaculatus (Mitch.), Horned Chub	3
	Siluridae	
	Ictalurus punctatus (Raf.), Channel Cat	80
	Centrarchidae	
	Ambloplites rupestris (Raf.), Rock Bass	1
	Micropterus dolomieu Lac., Small-mouthed Bass	1
Cyclochaeta domerqui Wallengren .47%	Centrarchidae	
	Apomotis cyanellus (Raf.), Green Sunfish	1
Chilodon sp. 1.43%	Centrarchidae	
	Helioperca macrochira (Raf.), Blue-nosed Sunfish	1
	Huro salmoides (Lac.), Large-mouthed Bass	1
	Micropterus dolomieu Lac., Small-mouthed Bass	1
Protozoan, mixed infection 1.43%	Siluridae	
	Ameiurus nebulosus (Le S.), Common Bullhead	1
	Centrarchidae	
	Micropterus dolomieu Lac., Small-mouthed Bass	2
Myxobolus sp. .47%	Centrarchidae	
	Chaenobryttus gulosus (Cuv.), Warmouth	1

[1] Percentage of total number of recorded deaths.

Gyrodactyloides (sp.?) 3.81%	Serranidae	
	Morone interrupta Gill, Yellow Bass	8
Argulus sp. .47%	Lepisosteidae	
	Lepisosteus osseus (L.), Long-nosed Gar	1
Cestode Enteritis .47%	Esocidae	
	Esox estor Le S., Pike	1
Gastritis .47%	Amiidae	
	Amia calva L., Bowfin	1
Malnutrition .95%	Catostomidae	
	Catostomus commersonii (Lac.), Common sucker	1
	Hypentelium nigricans (Le S.), Hog Sucker	1
Edema 2.38%	Cyprinidae	
	Carassius auratus (L.), Goldfish	2
	Scardinius erythrophthalmus (L.), Pearl Roach	2
	Centrarchidae	
	Micropterus dolomieu Lac., Small-mouthed Bass	1
Ovarian degeneration 2.38%	Acipenseridae	
	Scaphirhynchus platorhynchus (Raf.), Shovel-nosed Sturgeon	1
	Salmonidae	
	Salvelinus fontinalis (Mitch.), Brook Trout	1
	Salvelinus fontinalis (Mitch.), Albino Brook Trout	1
	Centrarchidae	
	Micropterus dolomieu Lac., Small-mouthed Bass	1
	Percidae	
	Perca flavescens (Mitch.), Yellow Perch	1
Myxomata? 6.19%	Salmonidae	
	Salmo fario (Turton), Brown Trout	3
	Salmo irideus Gibbons, Rainbow Trout	2
	Centrarchidae	
	Helioperca macrochira (Raf.), Blue-nosed Sunfish	2
	Huro salmoides (Lac.), Large-mouthed Bass	2
	Micropterus dolomieu Lac., Small-mouthed Bass	4
Epithelioma .47%	Salmonidae	
	Salvelinus fontinalis (Mitch.), Albino Brook Trout	1
Scoliosis .47%	Acipenseridae	
	Scaphirhynchus platorhynchus (Raf.), Shovel-nosed Sturgeon	1

Lordosis .47%	Acipenseridae	
	Acipenser fulvescens Raf., Lake Sturgeon	1
Senility? 1.43%	Amiidae	
	Amia calva L., Bowfin	1
	Centrarchidae	
	Helioperca macrochira (Raf.), Blue-nosed Sunfish	1
	Lepomis auritus (L.), Red-breasted Sunfish	1
Chemical poisoning 5.24%	Esocidae	
	Esox masquinongy Mitch., Muskellunge	11
Destroyed .47%	Cyprinidae	
	Chrosomus erythrogaster Raf., Red-bellied Dace	1
Water temperature 13.3%	Salmonidae	
	Salmo irideus Gibbons, Rainbow Trout	5
	Salvelinus fontinalis (Mitch.), Brook Trout	23
Unknown 5.24%	Salmonidae	
	Salmo salar sebago Girard, Land-locked Salmon	2
	Cyprinidae	
	Cyprinus carpio L., Carp	1
	Rhinichthys atratulus (Hermann), Black-nosed Dace	1
	Centrarchidae	
	Eupomotis gibbosus (L.), Pumpkin Seed	4
	Pomoxis sparoides (Lac.), Calico Bass	2
	Percidae	
	Perca flavescens (Mitch.), Yellow Perch	1

TABLE III

Causes of Mortality in Tropical Fresh-water Fishes.

DISEASE	FISH	No. DEATHS
Saprolegnia sp. 1.81%[1]	Gymnotidae	
	Electrophorus electricus (L.), Electric Eel	4
	Symbranchidae	
	Symbranchus marmoratus Bloch	1
Ichthyophthirius multifiliis Fouquet 1.81%	Characinidae	
	Cheirodon piaba Lütken	5
Stregeid .36%	Toxotidae	
	Toxotes jaculator (Pallas), Archerfish	1
Ovarian cysts .36%	Cyprinodontidae	
	Rivulus harti Boulenger	1

[1] Percentage of total number of recorded deaths.

Failure to deliver young 2.53%	Poeciliidae	
	Mollienisia sphenops (C. & V.), Mollie	2
	Xiphophorus hellerii Heckel, Swordtail	2
	Swordtail X Platy Hybrid	3
Egg bound 3.25%	Characinidae	
	Copeina arnoldi Regan, Splashing Salmlet	1
	Epicyrtus microlepis Reinhardt, Glass Characin	1
	Hyphessobrycon bifasciatus Ellis, Yellow Tetra	1
	Gymnotidae	
	Eigenmannia virescens (Val.), Glass Gymnotid	1
	Gymnotus carapo L., Banded Gymnotid	1
	Cyprinidae	
	Barbus conchonius Ham-Buch., Rosy Barb	1
	Barbus cummingti Gthr.	1
	Cichlidae	
	Aequidens moronii Steindachner	1
	Geophagus surinamensis (Bloch)	1
Hepatic degeneration .36%	Anabantidae	
	Trichogaster trichopterus (Pallas), Hairfin Gourami	1
Edema 2.17%	Cyprinidae	
	Barbus conchonius Ham.-Buch., Rosy Barb	1
	Siluridae	
	Acanthodoras cataphractus (L.)	1
	Anabantidae	
	Betta splendens Regan, Siamese Fighting Fish	1
	Macropodus cupanus (C. & V.)	1
	Macropodus opercularis (L.), Forked-tail Paradise Fish	1
	Cichlidae	
	Aequidens latifrons (Steindachner)	1
Malnutrition 1.44%	Osteoglossidae	
	Osteoglossum bicirrhosum Vandelli, Arowana	1
	Poeciliidae	
	Mollienisia velifera Regan, Sailfin Mollie	1
	Cichlidae	
	Pterophyllum scalare (C. & V.), Angelfish	2
Chemical poisoning, paint .72%	Gymnotidae	
	Sternopygus macrurus (B. & S.)	2
Jumped from tank 1.08%	Polypteridae	
	Calamoichthys calabaricus (Smith), Reedfish	1

	Characinidae	
	Exodon paradoxus Müller & Troschel	1
	Siluridae	
	Clarias sp.	1
Senility? 7.58%	Polypteridae	
	Calamoichthys calabaricus (Smith), Reedfish	1
	Notopteridae	
	Xenomystus nigri Gthr., African Knife-fish	1
	Characinidae	
	Hyphessobrycon flammeus Myers, Flame Tetra	1
	Hyphessobrycon heterorhabdus (Ulrey)	1
	Hyphessobrycon serpae Durbin	1
	Moenkausia pittieri Eigenmann	1
	Mylossoma duriventris (Cuv.)	1
	Nannaethiops unitaeniatus Gthr.	1
	Pristella riddlei (Meek)	1
	Gymnotidae	
	Gymnotus coatesi LaMonte, Tiger Knifefish	1
	Cyprinidae	
	Barbus lineatus Duncker	2
	Esomus malayensis E. Ahl, Malayen Flying Barb	1
	Rasbora trilineata Steindachner, Three-lined Rasbora	1
	Aspridinidae	
	Bunocephalus bicolor Steindachner	1
	Siluridae	
	Acanthodoras sp.	1
	Poeciliidae	
	Belonesox belizanus Kner, Pike-killie	1
	Anabantidae	
	Ctenops vittatus (C. & V.), Croaking Gourami	1
	Ophiocephalidae	
	Channa asiatica (L.), Snake-head	1
	Nandidae	
	Badis badis (Ham.-Buch.)	1
	Cichlidae	
	Etroplus suratensis (Bloch)	1
Missing 2.53%	Cyprinidae	
	Rasbora trilineata Steindachner, Three-lined Rasbora	1
	Cyprinodontidae	
	Aphyosemion calliurum (Boulenger), Lyretail	1
	Poeciliidae	
	Belonesox belizanus Kner, Pike-killie	2

Missing (continued)	Hemirhamphidae	
	Dermogenys pusillus van Hasselt, Fresh-water Halfbeak	1
	Anabantidae	
	Helostoma temmincki C. & V., Kissing Gourami	1
	Cichlidae	
	Crenicichla lepidota Heckel	1
Destroyed 1.81%	Siluridae	
	Acanthodoras sp.	1
	Loricariidae	
	Loricaria sp.	4
Water temperature 3.25%	Characinidae	
	Creatochanes melanurus (Bloch)	1
	Cyprinodontidae	
	Fundulus chrysotus Holbrook	1
	Fundulus ocellaris Jordan & Gilbert	1
	Oryzias latipes (Schl.), Medaka	1
	Cichlidae	
	Cichlosoma severum (Heckel), Deep-bodied cichlid	3
	Herichthys cyanoguttatus Baird and Girard	2
"Spoiled" water 4.70%	Dasyatidae	
	Potamotrygon hystrix (Müller & Troschel), Fresh-water Stingray	2
	Characinidae	
	Nannaethiops unitaeniatus Gthr.	2
	Cyprinidae	
	Barbus semifasciolatus Gthr., Half-banded Barb	2
	Cyprinodontidae	
	Rivulus harti Boulenger	4
	Poeciliidae	
	Micropoecilia branneri Eigenmann	2
	Cichlidae	
	Symphysodon discus (Heckel), Disc Cichlid	1
Fighting 8.30%	Characinidae	
	Copeina arnoldi Regan, Splashing salmlet	1
	Creatochanes melanurus (Bloch)	1
	Leporinus affinis Gthr.	1
	Leporinus fasciatus (Bloch), Black-ringed Groundfish	1
	Serrasalmus scapularis Gthr.	1
	Gymnotidae	
	Gymnotus carapo L., Banded Gymnotid	1
	Cyprinodontidae	
	Chriopeops goodei (Jordan)	1

	Epiplatys chaperi (Sauvage), Chaper's Panchax	3
	Panchax lineatus C. & V., Striped Panchax	3
	Anabantidae	
	Betta splendens Regan, Siamese Fighting Fish	3
	Macropodus opercularis (L.), Fork-tailed Paradise Fish	3
	Cichlidae	
	Cichlasoma cutteri Fowler	1
	Cichlasoma festivim (Heckel), Painted Cichlid	1
	Hemichromis bimaculatus Gill, Ruby Jewel Fish	1
	Hemichromis fasciatus Peters	1
Acclimatization 23.1%	Osteoglossidae	
	Osteoglossum bicirrhosum Vandelli	2
	Mormyridae	
	Mormyrus kannume Forskål	1
	Characinidae	
	Anoptichthys jordani Hubbs & Innes, Blind Characin	20
	Carnegiella strigata (Gthr.), Mottled Hatchetfish	7
	Chalceus macrolepidotus Cuv.	1
	Chilodus punctatus Müller & Troschel, Head-standing Fish	1
	Copeina arnoldi Regan, Splashing salmlet	3
	Corynopoma riisei Gill	4
	Gasteropelecus sternicla (L.), Hatchet-fish	3
	Hemigrammus rhodostomus E. Ahl, Red-mouthed Tetra	1
	Pterodiscus laevis, Eigenmann, Flying Characin	2
	Cyprinidae	
	Rasbora pauciperforata Weber & de Beaufort	3
	Callichthyidae	
	Corydoras sp.	1
	Cyprinodontidae	
	Aphyosemion calliurum (Boulenger), Lyretail	2
	Atherinidae	
	Telmatherina ladigesi E. Ahl	8
	Cichlidae	
	Cichlasoma cutteri Fowler	1
	Gobiidae	
	Boleophthalmus viridus Ham.-Buch.	4
Unknown 32.8%	Mormyridae	
	Mormyrus kannume Forskål	1

Unknown (continued)

Pantodontidae

Pantodon buchholzi Peters, Fresh-water Butterflyfish	1

Characinidae

Anostomus plicatus Eigenmann	1
Carnegiella strigata (Gthr.), Mottled Hatchetfish	1
Chalcinus elongatus Gthr.	1
Chalcinus rotundatus (Schomburk)	1
Epicyrtus microlepis Reinhardt, Glass Characin	2
Hemoidus gracilis Gthr.	1
Hemiodus quadrimaculatus Pellegrin	1
Hyphessobrycon innesi Hubbs, Neon Tetra	2
Myloplus schomburgkii (Jardine)	2
Poecilobrycon eques (Steindachner)	1
Poecilobrycon trifasciatus (Steindachner), Three-lined Pencilfish	2
Poecilobrycon unifasciatus (Steindachner), One-lined Pencilfish	1
Prochilodus insignis Schomburgk, Flagtail	1

Cyprinidae

Barbus conchonius Ham.-Buch., Rosy Barb	2
Barbus oligolepsis (Bleeker)	1
Barbus phutunio (Ham.-Buch.)	1
Barbus sp.	5
Danio malabaricus (Jerdon), Giant Danio	1
Notropis metallicus Jordan & Meek	3
Rasbora heteromorpha Duncker, Red Rasbora	1
Rasbora maculata Duncker	2

Cobitidae

Botia sp.	1

Siluridae

Centromochlus aulopygius Kner	1
Microglanis parahybae (Steindachner)	1

Callichthyidae

Corydoras arcuatus Ahl	1
Corydoras leopardus Myers	
Corydoras melanisteus Regan	1

Loricariidae

Loricaria parva Boulenger	1
Plecostomus sp.	1

Cyprinodontidae

Chriopeops goodei (Jordan)	1
Panchax lineatus C. & V., Striped Panchax	1

Poeciliidae

Belonesox belizanus Kner, Pike-killie	1
Limia nigrofasciata Regan	1
Limia vittata (Guichenot)	1
Mollienisia latipinna Le S., Mudpusser	2
Phalloceros caudomaculatus (Hensel)	4
Platypoecilus maculatus Gthr., Platy	10
Quintana atrizona Hubbs	1

Hemirhamphidae	
Dermogenys pusillus van Hasselt, Fresh-water Halfbeak	1
Anabantidae	
Colisa lalia (Ham.-Buch.), Dwarf Gourami	2
Ctenops vittatus (C. & V.), Croaking Gourami	4
Macropodus opercularis (L.), Fork-tailed Paradise Fish	3
Nandidae	
Badis badis (Ham.-Buch.)	1
Monocirrhus polyacanthus Heckel, Leaffish	4
Polycentrus schomburgkii Müller and Troschel, Casarab	1
Centrarchidae	
Elassoma evergladei Jordan, Pigmy sunfish	2
Cichlidae	
Apistogramma pertense, (Haseman), Dwarf Cichlid	1
Apistogramma sp.	1
Etroplus maculatus (Bloch), Orange Chromide	2
Geophagus jurupari Heckel, Demon Fish	1
Geophagus surinamensis (Bloch)	1
Tilapia zillii Gervais	1
Toxotidae	
Toxotes jaculator (Pallas), Archerfish	1

TABLE IV.

Causes of Deaths in Specimens Other Than Fishes.

DISEASE	AMPHIBIANS	No. DEATHS
Fungus	*Cryptobranchus alleganiensis* (Daudin), Hellbender	2
	Necturus maculosus (Raf.), Mudpuppy	5
	Proteus anguinus, Olm	2
Red-leg disease *Proteus hydrophilus* (Sanarelli)	*Pipa surinamensis*, Surinam Toad	1
Myxoma	*Necturus maculosus* (Raf.), Mudpuppy	2
	REPTILES	
Fungus 6.1%[1]	*Alligator mississipiensis* (Daudin), American Alligator	5
	Chelys fimbriata, Matamata	1
Liver abcess from nematodes 1.0%	*Natrix s. sipedon* (L.), Common Water Snake	1
Liver degeneration 1.0%	Guatemalan Turtle	1

[1] Percentage of total number of recorded deaths.

Fatty degeneration 7.1%	*Alligator mississipiensis* (Daudin), American Alligator	7
Malnutrition 6.1%	*Caiman jacuare* (Daudin)	1
	Caiman sclerops (Schneider)	4
	Gecko sp.	1
Enteritis 56.5%	*Caretta caretta* (L.), Loggerhead Turtle	1
	Chrysemys picta (Schneider), Painted Turtle	23
	Clemmys guttata (Schneider), Spotted Turtle	6
	Clemmys insculpta (Le Conte), Wood Turtle	6
	Graptemys p. pseudogeographica (Gray), Mississippi Map Turtle	1
	Podochemis expansa, Amazon River Turtle	1
	Pseudemys scripta troostii (Holbrook), Cumberland Turtle	8
	Pseudemys scripta ssp., Yellow-bellied Terrapin	1
	Terrapene carolina (L.), Box turtle	7
	Trionyx sp.	1
	Chinese River Turtle	1
Floating trouble? 1.0%	*Caretta caretta* (L.), Loggerhead Turtle	1
Fighting 2.0%	*Caiman sclerops* (Schneider)	1
	Caretta caretta (L.), Loggerhead Turtle	1
Drowned 7.1%	*Alligator mississipiensis* (Daudin), American Alligator	6
	Trionyx ferox (Schneider), Southern Soft-shelled Turtle	1
Unknown 12.1%	*Caiman niger* Spix	1
	Caretta caretta (L.), Loggerhead Turtle	1
	Caretta kempii (Garman), Kemp's Turtle	1
	Chelys fimbriata, Matamata	1
	Emys blandingii (Holbrook), Blanding's Turtle	1
	Graptemys geographica (Le S.), Map Turtle	1
	Malaclemys centrata (Latreille), Diamond-back Terrapin	1
	Macrochelys temminckii (Troost), Alligator Snapping Turtle	1
	Podochemis expansa, Amazon River Turtle	1
	Terrapene carolina (L.), Box Turtle	1
	Trionyx sp.	1
	East Indian Mud Turtle	1
	BIRDS	
Tuberculosis?	*Spheniscus demersus* (L.), Blackfoot Penguin	2
Fractured leg, Gangrene	*Spheniscus humboldti* Meyen, Humboldt's Penguin	1

	MAMMAL	
Malnutrition	*Trichechus inunguis* Natterer, Amazon Manatee	1
	INVERTEBRATES	
Larval trematodes on gills	*Scyllarides latus,* Flat Lobster	1
Fighting	*Octopus* sp.	3
Water chemistry	*Fasciolaria gigantea* Kiener, Giant Band Shell	1
	Fasciolaria tulipa L., Tulip Band Shell	1
	Limulus polyphemus (L.), Horseshoe Crab	10
	Calappa flammea (Herbst), Queen Crab	2
	Libinia dubia Milne-Edwards, Spider Crab	7
	Menippe mercenaria (Say), Stone Crab	2
	Panulirus argus (Latreille), Spiny Lobster	1
	Petrochirus bahamensis, Sea-soldier	1
	Squilla empusa, Mantis Shrimp	1
	Oreaster reticulatus, Giant Starfish	10
	Sargartia leucolena, White Anemone	35
Unknown	*Cambarus* sp., Fresh-water Crayfish	5
	Homarus americanus Milne-Edwards, Northern Lobster	2
	Papaloapan Fresh-water Crab	1

TABLE V.

Summary of Mortality Percentage by Causes.

Causes	*Marine*	*Fresh-water temperate*	*Fresh-water tropical*	*Amphibians*	*Reptiles*	*Birds*	*Mammals*	*Invertebrates*
Infectious disease	64.8	60.5	3.9	83.3	1.0	67	0	1.2
Non-infectious disease	19.5	21.0	32.2	16.7	86.9	33	100	3.6
Water conditions [1]	11.3	13.3	31.1	0	0	0	0	85.5
Unknown	4.4	5.2	32.8	0	12.1	0	0	9.7

[1] Includes density, temperature, pH. and chemical composition.

TABLE VI.

Summary of Mortality Percentage by Months.

	Marine	*Fresh-water temperate*	*Fresh-water tropical*	*Total*	*Amphibians*	*Reptiles*	*Birds*	*Mammals*	*Invertebrates*
January	2.7	0	7.6	3.4	8.3	3.0	0	0	2.4
February	4.6	2.9	5.4	4.5	0	5.1	33.3	0	1.2
March	4.3	0	12.3	5.2	0	11.1	0	0	0
April	5.1	1.0	8.7	5.2	8.3	6.1	0	0	3.6
May	7.2	6.7	15.5	8.8	8.3	21.2	33.3	0	1.2
June	8.4	3.3	5.8	7.1	0	5.1	0	0	1.2
July	35.5	16.2	16.6	28.9	0	12.1	0	0	7.2
August	12.4	3.3	6.6	9.9	0	6.1	0	100	30.1
September	6.7	2.9	7.6	6.2	16.7	10.1	0	0	9.6
October	5.6	4.3	4.3	5.2	16.7	3.0	0	0	13.2
November	4.1	25.7	5.4	7.6	0	5.1	0	0	18.1
December	3.5	33.8	4.3	8.1	41.7	12.1	33.3	0	12.1

TABLE VII.

Summary of Mortality Percentage of Fishes by Sex.

	Marine	*Fresh-water temperate*	*Fresh-water tropical*	*Total*
Male	27.9	14.8	23.5	25.1
Female	37.2	39.0	35.0	37.0
Immature	5.9	40.5	9.4	11.8
Undetermined	29.0	5.7	32.1	26.1

TABLE VIII.

Longevity of Specimens which Died During 1939.

Longevity	*% of 925 marine fishes*	*% of 210 fresh-water temperate fishes*	*% of 277 fresh-water tropical fishes*	*% average of all fishes*	*% of 12 amphibians*	*% of 99 reptiles*	*% of 3 birds*	*% of one mammal*	*% of 83 invertebrates*
Unknown	—	—	6.9	1.3	—	—	—	—	—
One month or less	55.5	27.6	22.0	44.8	0	9.1	33.3	100.	12.0
Two to twelve months	39.3	60.0	50.2	44.5	100.	87.9	0	0	88.0
More than one year	5.2	12.4	20.9	9.4	0	3.0	66.7	0	0

Table IX.

Fishes Over Two Years Old which Died During 1939.[1]

Marine

Ten Years
- *Gymnothorax funebris* Ranzani, Green Moray

Seven Years
- *Tilapia mossambica* Peters

Six Years
- *Ginglymostoma cirratum* (Bonnaterre), Nurse Shark

Five Years
- *Trachinotus glaucus* (Bloch), Palmoneta
- *Sciaenops ocellatus* (Linnaeus), Channel Bass
- *Mycteroperca bonaci* (Poey), Black Grouper

Four Years
- *Acipenser oxyrhynchus* Mitchill, Common Sturgeon
- *Galeichthys felis* (Linnaeus), Sea Catfish
- *Gymnothorax moringa* (Cuvier), Spotted Moray
- *Seriola zonata* (Mitchill), Rudder-fish
- *Pogonias cromis* (Linnaeus), Sea Drum
- *Halichaeres radiatus* (Linnaeus), Puddingwife
- *Thalassoma bifasciatus* (Bloch), Blue-head

Three Years
- *Tarpon atlanticus* (Cuvier & Valenciennes), Tarpon
- *Roccus lineatus* (Bloch), Striped Bass
- *Scatophagus argus* (Bleeker), Scat

Two Years
- *Epinephelus striatus* (Bloch), Nassau Grouper
- *Rypticus saponaceus* (Bloch & Schneider), Soapfish
- *Dascyllus aruanus* (Linnaeus), Jesuite
- *Chaetodipterus faber* (Broussonet), Spadefish
- *Balistes vetula* Linnaeus, Queen Triggerfish
- *Diodon hystrix* Linnaeus, Porcupine Fish

Temperate Fresh-water

Six Years
- *Lepisosteus osseus* (Linnaeus), Long-nosed Gar
- *Amia calva* Linnaeus, Bowfin

Five Years
- *Acipenser fulvescens* Rafinesque, Lake Sturgeon
- *Huro salmoides* (Lacépède), Large-mouthed Bass
- *Morone interrupta* Gill, Yellow Bass

Four Years
- *Scaphirhynchus platorhynchus* (Rafinesque), Shovel-nosed Sturgeon
- *Esox masquinongy* Mitchill, Muskellunge
- *Ambloplites rupestris* (Rafinesque), Rock Bass
- *Lepomis auritus* (Linnaeus), Red-breasted Sunfish
- *Helioperca macrochira* (Rafinesque), Blue-nosed Sunfish

Three Years
- *Scardinius erythrophthalmus* (Linnaeus), Pearl Roach
- *Ameiurus nebulosus* (Le Sueur), Common Bullhead
- *Perca flavescens* (Mitchill), Yellow Perch

Two Years
- *Salvelinus fontinalis* (Mitchill), Albino Brook Trout
- *Pomoxis sparoides* (Lacépède), Calico Bass

Tropical Fresh-water

Six and One-half Years
- *Channa asiatica* (Linnaeus), Snake-head

Five Years
- *Hyphessobrycon heterorhabdus* (Ulrey)
- *Hyphessobrycon serpae* Durbin
- *Pristella riddlei* (Meek)
- *Serrasalmus scapularis* Günther

Four Years
- *Moenkhausia pittieri* Eigenmann
- *Gymnotus coatesi* LaMonte, Tiger Knifefish
- *Ctenops vittatus* (Cuvier & Valenciennes), Croaking Gourami
- *Aequidens moronii* Steindachner

Three Years
- *Calamoichthys calabaricus* (Smith), Reedfish
- *Esomus malayensis* E. Ahl, Malayan Flying Barb
- *Rasbora trilineata* Steindachner, Three-lined Rasbora
- *Etroplus suratensis* (Bloch)

Two and One-half Years
- *Xenomystus nigri* Günther, African Knifefish
- *Barbus lineatus* Duncker

Two Years
- *Mylossoma duriventris* (Cuvier)
- *Cheirodon piaba* Lütken
- *Rasbora heteromorpha* Duncker, Red Rasbora
- *Rasbora maculata* Duncker
- *Bunocephalus bicolor* Steindachner
- *Acanthodoras* sp.
- *Centromochlus aulopygius* Kner
- *Microglanis parahybae* (Steindachner)
- *Badis badis* (Hamilton-Buchanan)
- *Cichlasoma festivum* (Heckel), Painted Cichlid
- *Herichthys cyanoguttatus* Baird & Girard
- *Symbranchus marmoratus* Bloch

[1] Includes only oldest specimen of each species.

TABLE X.

Parasites and Hosts Observed in 1939.[1]

Parasite	*Host*	*Site of Infection*
I. Protozoa		
A. Marine species		
1. *Protrichomonas* sp.	*Chilomycterus schoepfii* (Walbaum)	Intestine
2. *Oodinium ocellatum* Brown	Marine fishes	Gills
3. *Trichodina* sp.	Marine fishes	Gills
B. Fresh-water species		
4. *Cyclochaeta domerqui* Wallengren	Fresh-water fishes	Skin & gills
5. *Chilodon* sp.	Fresh-water fishes	Skin & gills
6. *Ichthyophthirius multifiliis* Fouquet	Fresh-water fishes	Skin & gills
7. *Henneguya ameiurensis*[2] Nigrelli & Smith	*Ameiurus nebulosus* (Le Sueur)	Skin
8. *Myxobolus* sp.	*Chaenobryttus gulosus* (Cuvier)	Gills
II. Trematoda, monogenetic		
A. Marine species		
9. *Epibdella melleni* MacCallum	Marine fishes	Skin & eyes
10. *Microcotyle* sp.	Marine fishes	Gills
11. *Diplectanus* sp.	Marine fishes	Gills
12. Gyrodactyloides (Spp?)	*Fundulus heteroclitus* (Linnaeus)	Skin & gills
B. Fresh-water species		
13. Gyrodactyloides (Spp?)	Fresh-water fishes	Skin & gills
III. Trematoda, digenetic adults		
A. Marine species		
14. *Lintonium vibex* (Linton)	*Spheroides maculatus* (Bloch & Schneider)	Pharynx
15. *Bianium plicitum* (Linton)	*Spheroides maculatus* (Bloch & Schneider)	Intestine
16. *Probliotrema* sp.	*Amphotistius sabinus* (Le Sueur)	Body cavity
17. *Tubulovesicula madurensis*[3] Nigrelli	*Scorpaena madurensis* (Cuvier & Valenciennes)	Stomach
18. Hemiuridae (Spp?)	Marine fishes	Stomach
19. *Podocotyle atzi* Nigrelli[3]	*Scorpaena madurensis* (Cuvier & Valenciennes)	Intestine
20. Allocreadiidae (Spp?)	Marine fishes	Intestine
21. *Nematobothrium* sp.	*Sarda sarda* (Bloch)	Gills
22. *Sterrhurus branchialis* Stunkard & Nigrelli	*Trichiurus lepturus* Linnaeus	Gills
B. Fresh-water species		
23. *Allacanthochasmus varius* Vancleave	*Morone interrupta* Gill	Intestine
24. *Allacanthochasmus artus* Vancleave & Mueller	*Morone interrupta* Gill	Intestine
25. *Neochasmus umbellus* Vancleave & Mueller	*Morone interrupta* Gill	Intestine
26. *Bucephalus pusillis* (Stafford)	*Stizostedion vitreum* (Mitchill)	Intestine
27. *Allocreadium* sp.	*Eupomotis gibbosus* (Linnaeus)	Intestine
28. *Crepidostomum* sp.	*Helioperca macrochira* (Rafinesque)	Intestine
29. Amphistome (Sp?)	*Trichechus manatus latirostrus* (Harlan)	Caecum

[1] Including species and specimens not on exhibition at the N. Y. Aquarium.
[2] See Nigrelli & Smith, 1940
[3] See Nigrelli, 1940b.

IV. Trematoda, digenetic larvae		
A. Marine fishes		
30. *Cryptocotyle lingua* (Creplin)	*Tautoga onitis* (Linnaeus)	Encysted on skin & fins
31. Metacercaria (Sp?)	*Scyllarides latus*	Encysted on gills
B. Fresh-water species		
32. *Neascus vancleavi* (Agersbord)	Fresh-water fishes	Organs
33. *Clinostomum complanatum* (Rudolphi)	Fresh-water fishes	Skin
V. Cestoda, adults		
A. Marine species		
34. *Calliobothrium verticillatum* (Rudolphi)	*Mustelus canis* (Mitchill)	Intestine
35. *Crossobothrium laciniatum* Linton	*Carcharias littoralis* (Mitchill)	Intestine
B. Fresh-water species		
36. *Proteocephalus* sp.	*Huro salmoides* (Lacépède)	Intestine
37. *Proteocephalus pinguis* LaRue	*Esox estor* Le Sueur	Intestine
38. *Corallobothrium* sp.	*Ictalurus punctatus* (Rafinesque)	Intestine
39. *Bothriocephalus cuspidatus* Cooper	*Perca flavescens* (Mitchill)	Intestine
VI. Cestoda, larvae		
A. Marine species		
40. *Otobothrium crenacolle* Linton	*Poronotus tricanthus* (Peck)	Encysted around vertebrae
41. Tetrarhynchid forms	Marine fishes	Intestine
42. Tetrarhynchid forms	Groupers	Encysted in body cavity
B. Fresh-water species		
43. *Ligula intestinalis* (Goeze)	*Hyborhynchus notatus* (Rafinesque)	Intestine
VII. Nematoda		
A. Fresh-water species		
44. *Camallanus* sp.	Fresh-water fishes	Intestine
45. *Spinitectis* sp.	*Micropterus dolomieu* Lacépède	Intestine
VIII. Hirudinea		
A. Marine species		
46. *Branchellion ravenelli*[4] (Girard)	*Dasyatis hastatus* (De Kay)	Skin
47. *Pontobdella muricata* (Linnaeus)	*Sphyrna zygaena* (Linnaeus)	Skin
B. Fresh-water species		
48. *Placobdella parasitica* (Say)	Fresh-water turtles	Skin
IX. Copepoda		
A. Marine species		
49. *Sphyrion lumpi* (Krøyer)	*Sebastes marinus* (Linnaeus)	Body
50. *Chondrancanthopsis nodosus* (Muller)	*Sebastes marinus* (Linnaeus)	Gills
51. *Penella instructa* Wilson	*Xiphias gladius* Linnaeus	Body
52. *Ergasilidae* (Spp?)	Marine fishes	Gills
53. *Pandarus bicolor* Leach	*Mustelus canis* (Mitchill)	Skin
54. *Lernaeenicus radiatus* (Le Sueur)	*Menidia menidia* (Linnaeus)	Body

[4] See Meyer, 1939.

B. Fresh-water species		
55. *Lernae* sp.	*Carassius auratus* (Linnaeus)	Body
56. *Argulus* spp.	Fresh-water fishes	Skin
57. *Ergasilus* sp.	Fresh-water fishes	Gills

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EXPLANATION OF THE PLATES.

All photographs by S. C. Dunton of the New York Aquarium.

Figs. 1 and 2. Queen triggerfish, showing peculiar ulceration of the skin around the mouth and fins. The causative agent is unknown.

Fig. 3. Edematous condition in pearl roach. A general anasarca was present and the kidneys were completely degenerated.

Fig. 4. Viscera of small-mouthed bass, showing ovarian degeneration. This condition results from the failure to spawn and to resorb the eggs.

Fig. 5. Portion of intestine of pike with heavy infestation of *Proteocephalus pinguis.* This infection was acquired in the wild state, since the fish lived but two months in captivity. The entire intestine was practically filled with these cestodes. Note the severe hemorrhage produced.

Fig. 6. Intestine of blue-nosed sunfish with hemorrhagic islands caused by intestinal flukes. Not included in Table II.

Fig. 7. Transverse section of alligator tail showing fatty degeneration. Large fat masses have pushed aside the muscles. Within these masses may be seen numbers of dark areas, consisting of hard, granular, yellowish material.

FIG. 1.

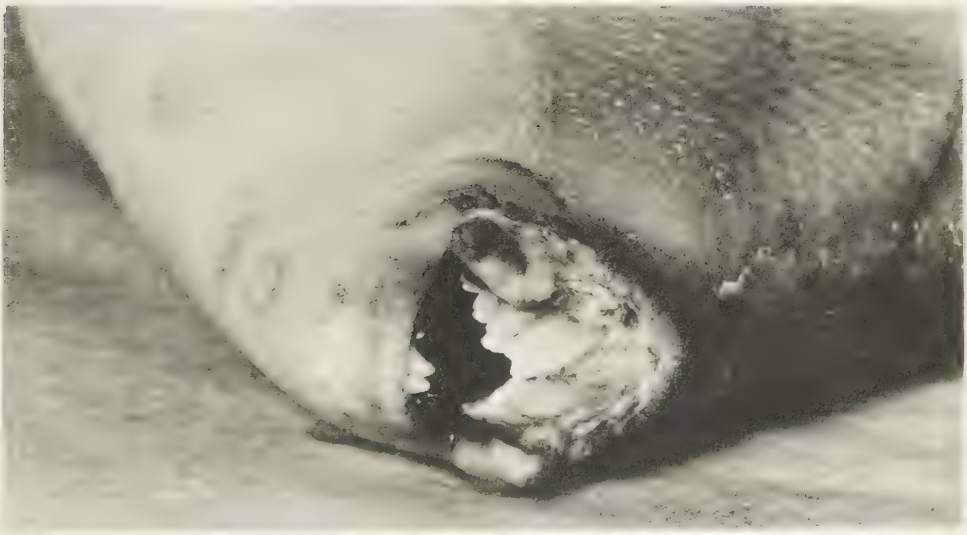

FIG. 2

MORTALITY [illegible]

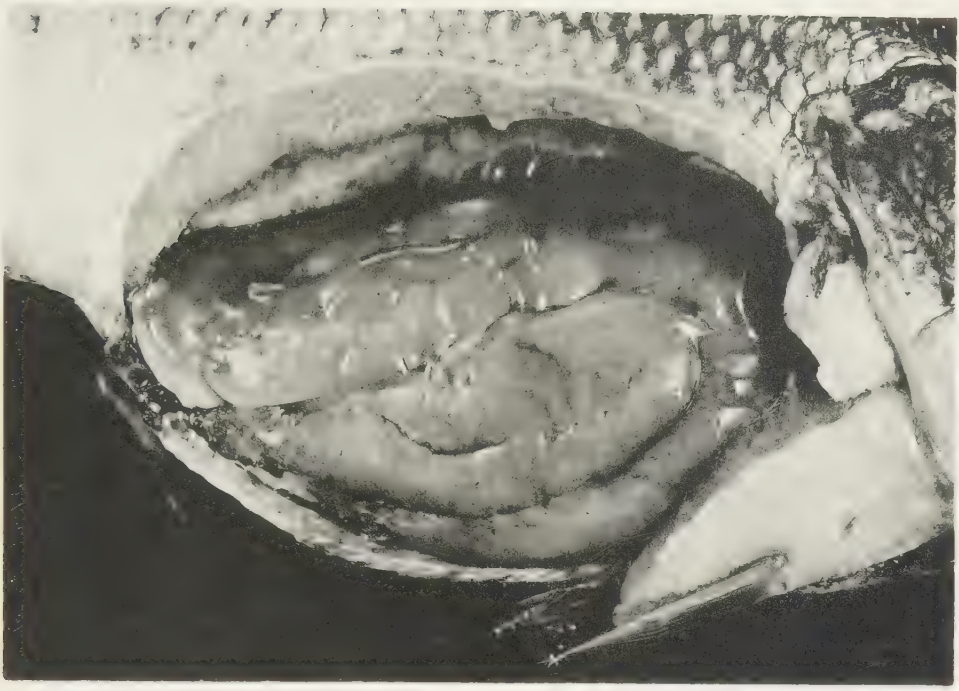

FIG. 4

FIG. 5

MORTALITY STATISTICS FOR ANIMALS IN THE NEW YORK [illegible]

FIG. 6

FIG. 7

MORTALITY [illegible] ANIMALS [illegible] IN THE NEW YORK AQUARIUM [illegible]

34.

A Comparison of Some Electrical and Anatomical Characteristics of the Electric Eel, *Electrophorus electricus* (Linnaeus).

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(Text-figures 1-7).

In a previous paper[2] it has been shown that the major and minor electrical discharges of the electric eel, *Electrophorus electricus* (Linnaeus), are produced respectively by the large organs and the organs of Sachs. It has also been shown[3] that the current produced in a conductor joining two points along an electric organ could be approximately accounted for by ascribing to the segment of the organ between the two points a constant electromotive force and a variable internal resistance and considering it shunted by a constant leakage resistance which may be attributed to the adjacent tissue. Except during the discharge the internal resistance of the segment is assumed to be so much higher than the leakage resistance that the potential difference is negligible between different points along the organ. The discharge is attributed to a transient drop in the internal resistance, allowing the electromotive force to produce a current.

Let R denote the internal resistance of a segment of the organ at the peak of the discharge, when the resistance is at its minimum. Let E denote the electromotive force of the segment and let r denote the leakage resistance, of the adjacent tissue. Let R′ denote the resistance of a conductor connected between electrodes in contact with the fish at the ends of the segment and let V denote the potential difference between these electrodes at the peak of the discharge. Then these quantities may be shown to be related by an equation, which may for the present purpose conveniently be written in the form

$$\frac{E}{V} = \frac{R}{R'} + \frac{r+R}{r} \quad . \qquad (1)$$

[1] Now at Department of Physics, University of California at Los Angeles.

[2] Coates, C. W., R. T. Cox, & L. P. Granath. The Electric Discharge of the Electric Eel, *Electrophorus electricus* (Linnaeus). *Zoologica*, Vol. XXII (Part 1), No. 1, April 5, 1937.

[3] Cox, R. T., & C. W. Coates. Electrical Characteristics of the Electric Tissue of the Electric Eel, *Electrophorus electricus* (Linnaeus). *Zoologica*, Vol. XXIII (Part 2), No. 8, July 14, 1938.

If R′ is varied in this equation, V varies with it in such a way that for every change in 1/R′ there is a proportional change in 1/V. Consequently the graph of 1/V plotted against 1/R′ will be a straight line. In Text-fig. 1 are plotted measurements of peak voltages obtained with various external resistances joined to electrodes 10 cm. apart on the large organ of an electric eel 103 cm. long. The sets of points indicated by different signs show sets of observations made at several different times. It will be seen that the points fall near to a straight line. (It should perhaps be pointed out that this does not prove the hypothesis of a variable internal resistance and constant electromotive force. This must be based upon other evidence discussed in the previous paper. The equation just given would still be valid if the internal resistance were constant and the electromotive force variable).

From the equation (1), when 1/R′ is zero, then

$$V = \frac{E\ r}{r + R} \cdot \qquad (2)$$

This corresponds to the case in which there is no external conductor between the electrodes. If the leakage resistance r is much greater than the internal resistance R, the observed peak voltage V will be nearly equal to the electromotive force E.

If, in the equation (1),1/V is set equal to zero, then

$$\frac{1}{R'} = -\left(\frac{1}{r} + \frac{1}{R}\right) \cdot \qquad (3)$$

Since negative values of the resistances are impossible, this case corresponds to no actual observation. But the line determined by the actual observations may nevertheless be extended, as in Text-fig. 1, to meet the axis of 1/R′ and the intercept may be noted to determine 1/r + 1/R. If the leakage resistance r is otherwise known, this last result makes it possible to determine R, the internal resistance of the segment of the electric organ. With both these resistances known, the intercept on the axis of 1/R′ may be used to determine the electromotive force E.

With the electric eel already mentioned the leakage resistance r was measured between electrodes 10 cm. apart along the portion of the body containing the electric organs. The measurement was made by observing the current passing through the body of the eel between the electrodes when a measured potential difference was applied to them. The peak voltages produced between the same electrodes in the same positions on the fish with various resistances connecting them were measured in both the major and minor discharge by means of a cathode-ray oscillograph. The electromotive force and the internal resistance of each segment 10 cm. long down the length of the organs were determined as already explained and as illustrated by Text-fig. 1.

The results of these observations and computations are shown in Table I for the major discharge and Table II for the minor discharge. The distances recorded in the first column of each table are measured from the anterior end of the anal fin, which is a convenient point of reference almost at the anterior end of the large organ.

TABLE I.

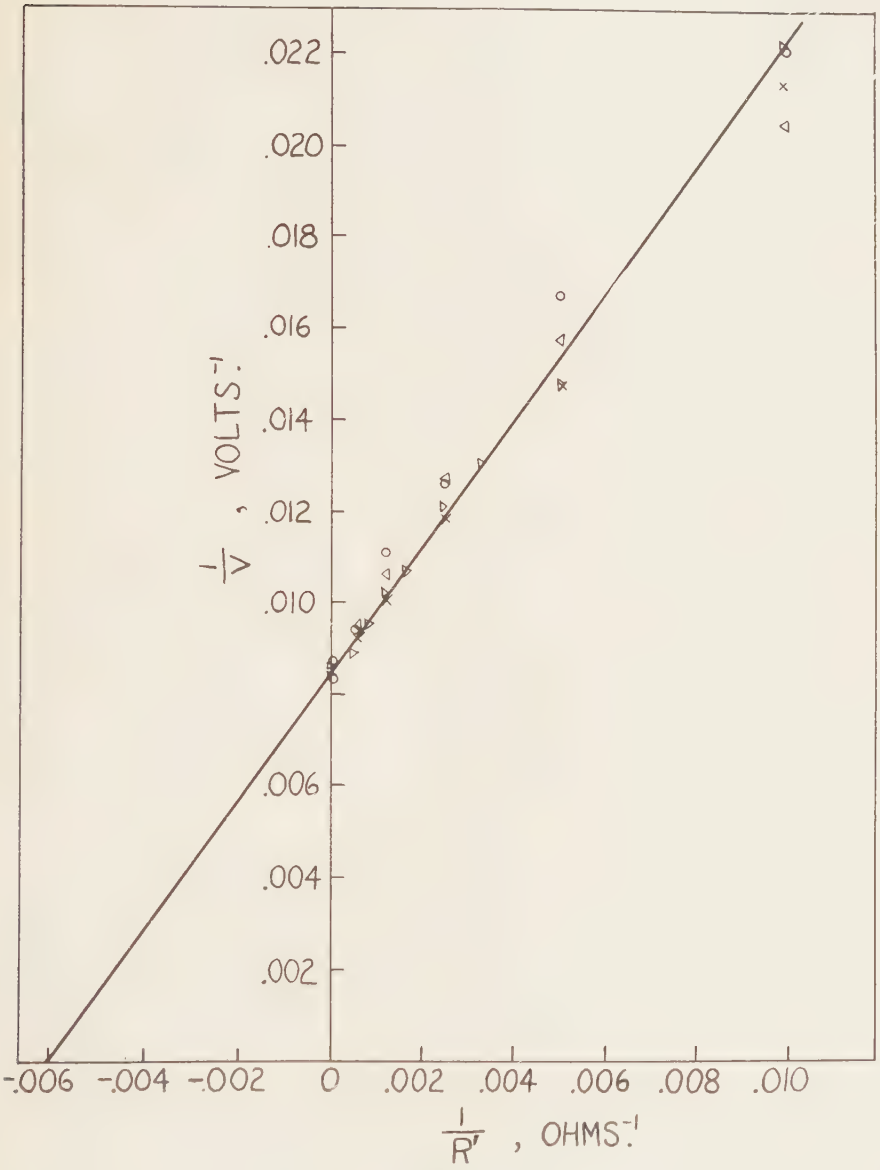
Major Discharge.

Positions of Electrodes, cm.	r, ohms	R, ohms	E, volts
0, 10	750	175	160
10, 20	765	210	150
20, 30	725	210	130
30, 40	675	180	90
40, 50	600	215	60
50, 60	550	325	30
60, 70	625	605	22
&			
60, 80	1215	850	32

TABLE II.

Minor Discharge.

Positions of Electrodes, cm.	r, ohms	R, ohms	E, volts
30, 40	675	475	4.8
40, 50	600	365	7.7
50, 60	550	365	12
60, 70	625	475	20
70, 80	925	780	22



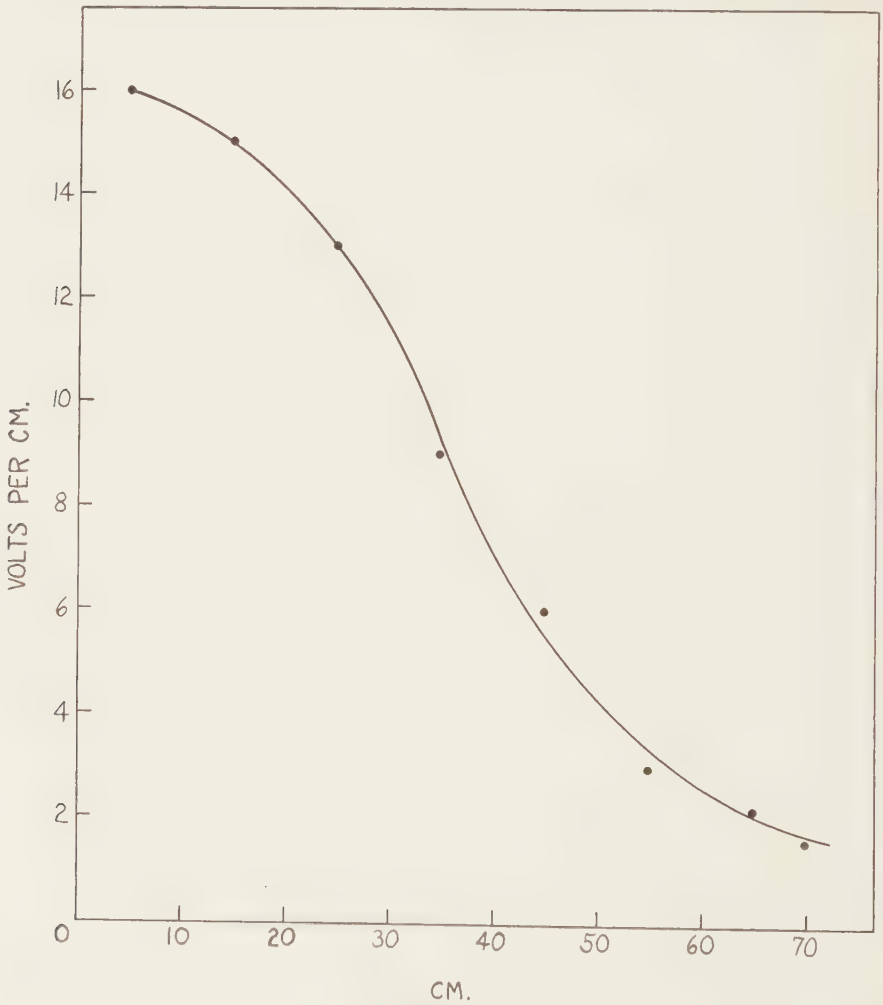
Text-fig. 1.

Major discharge. Electrodes at 10 cm. and 20 cm. from anterior end of anal fin. Reciprocal peak voltage vs. reciprocal external resistance.

It is hard to estimate the accuracy of these results. As regards the leakage resistance r, it is not so much the accuracy of the measurement itself which is in question as the accuracy of the assumption that all the current caused to flow in the adjacent tissue by the discharge of a segment of the organ can be treated as following a single path. As was pointed out in the paper already referred to[3] and as must indeed be rather obvious, this can be only a crude approximation. The error in this assumption will impair the accuracy of the determination of the internal resistance R, which is subject also to the errors of the extrapolation in the graphical method illustrated in Text-fig. 1. In what follows we are principally interested in the electromotive force E. Its values are computed from the values of the resistances and the measured values of the peak voltage by the equation

$$E = V \frac{r+R}{r} \tag{4}$$

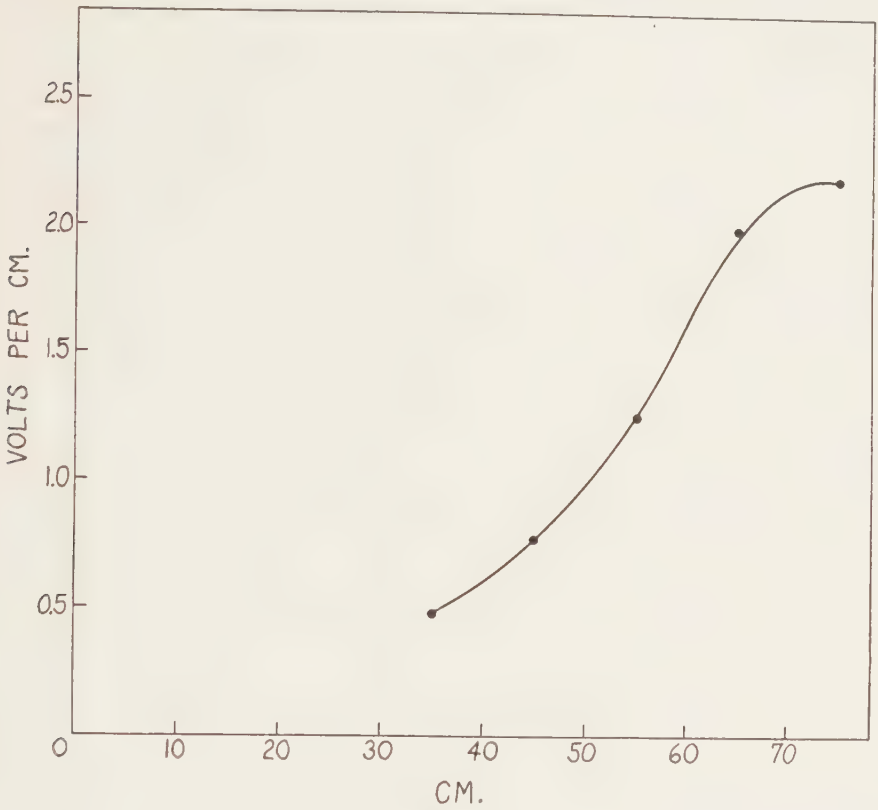
in which V is the peak voltage observed with no external conductor between the electrodes. It is seen in Table I that for about 50 cm. along the fish from



Text-fig. 2.

Major discharge. Electromotive force per cm. vs. distance along organs from anterior end of anal fin.

the anterior end of the large electric organ the measured values of r are much larger than the computed values of R in the major discharge. It seems probable that here the electromotive force actually is, as it is represented by the equation, not much greater than the peak voltage observed with no external conductor. In this case the ambiguities involved in the values of the resistances will not be very important in the determination of the electromotive force. We think it likely that the first five values of the electromotive force in Table I are not in error by more than about 10 per cent. The other values of Table I and those of Table II we consider rather more doubtful.



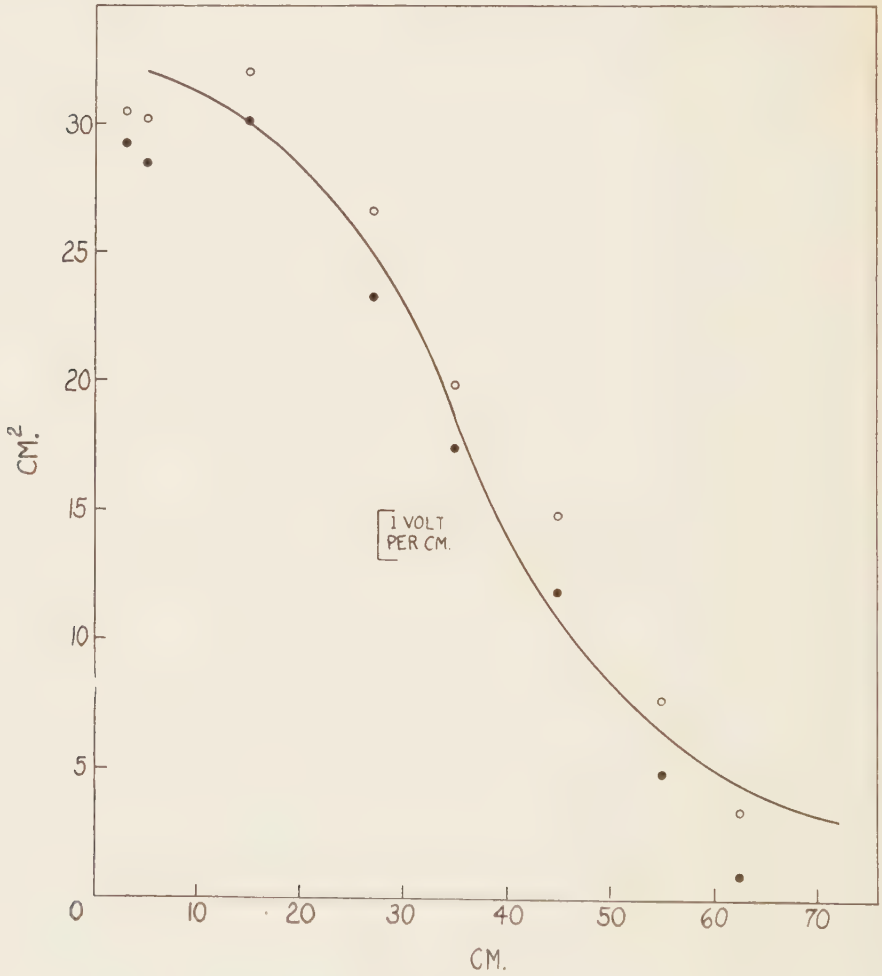
Text-fig. 3.

Minor discharge. Electromotive force per cm. vs. distance along organs from anterior end of anal fin.

In Text-fig. 2 the electromotive force per cm. of the major discharge, as reckoned from the data of Table I, is plotted as ordinate against the distance along the fish as abscissa. For plotting the first point on the left the average value of the electromotive force per cm. between electrodes at 0 and 10 cm. is taken as the value at 5 cm., and similarly for the other plotted points. Text-fig. 3 is a similar graph for the minor discharge plotted from the data of Table II.

After the measurements of the voltage and resistance were made, the fish was killed and its body transsected at a number of places. At these places the areas of the cross sections of the electric organs were measured. In Text-fig. 4 the black dots show the cross-sectional area of the large organ at various points along the fish, measured as in the other data from the anterior end of the anal fin. The white dots in the same figure show the sum

of the cross-sectional areas of the large organ and the organ of Hunter. For comparison the curve from Text-fig. 2, showing the electromotive force per cm. of the major discharge at points along the organ, has also been drawn in the figure, to the scale of volts per cm. indicated by the bracket. The fall of the plotted points along the curve is very striking. It is plain that there is a rather close proportionality between the electromotive force per cm. of the major discharge and the cross-sectional area either of the large organ alone or of the large organ and Hunter's organ together. Because of the small cross-section of Hunter's organ the ratio of area to electromotive force per cm. is not much different whether Hunter's organ be included or left out. In either case, for each 0.5 sq. cm. of cross-sectional area at any point there is found at the same point an electromotive force of approximately 1 volt per cm. along the axis of the organs. By varying the scale, either set of points can be brought closer to the curve than the other set. The best fit of the points which show the cross-section of both organs seems to be a little closer

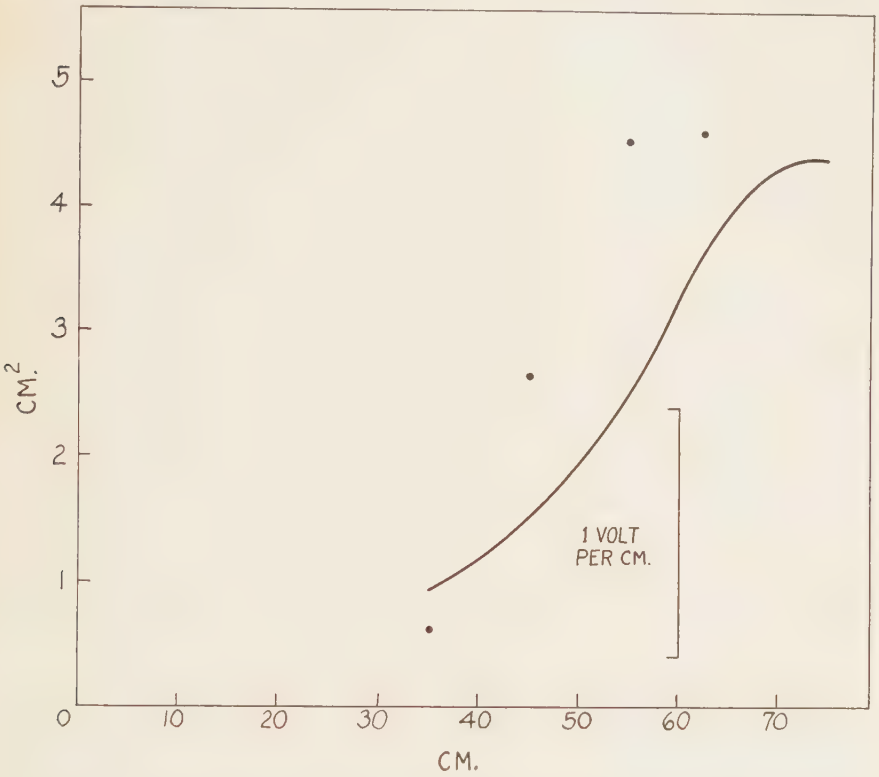


Text-fig. 4.

Curve: major discharge, electromotive force per cm. vs. distance along organs. Black dots: Large organ, cross-sectional area vs. distance along organs. White dots: Large organ and Hunter's organ, cross-sectional area vs. distance along organs.

than the best fit of the points showing the cross-section of the large organ alone, but there is not much to choose between the two.

The significance of this proportionality between the electromotive force per cm. and the cross-sectional area is not yet clear. If, in the discharge, the current were the same through every cross-section of the organ, then the observed relation would mean that equal quantities of power were generated in equal volumes of the electric tissue, since power is the product of electromotive force and current. But the current can scarcely be continuous along the organ when the fish discharges under water, since the whole skin is conducting.



Text-fig. 5.

Curve: minor discharge, electromotive force per cm. vs. distance along organs. Dots: Sachs' organ, cross-sectional area vs. distance along organs.

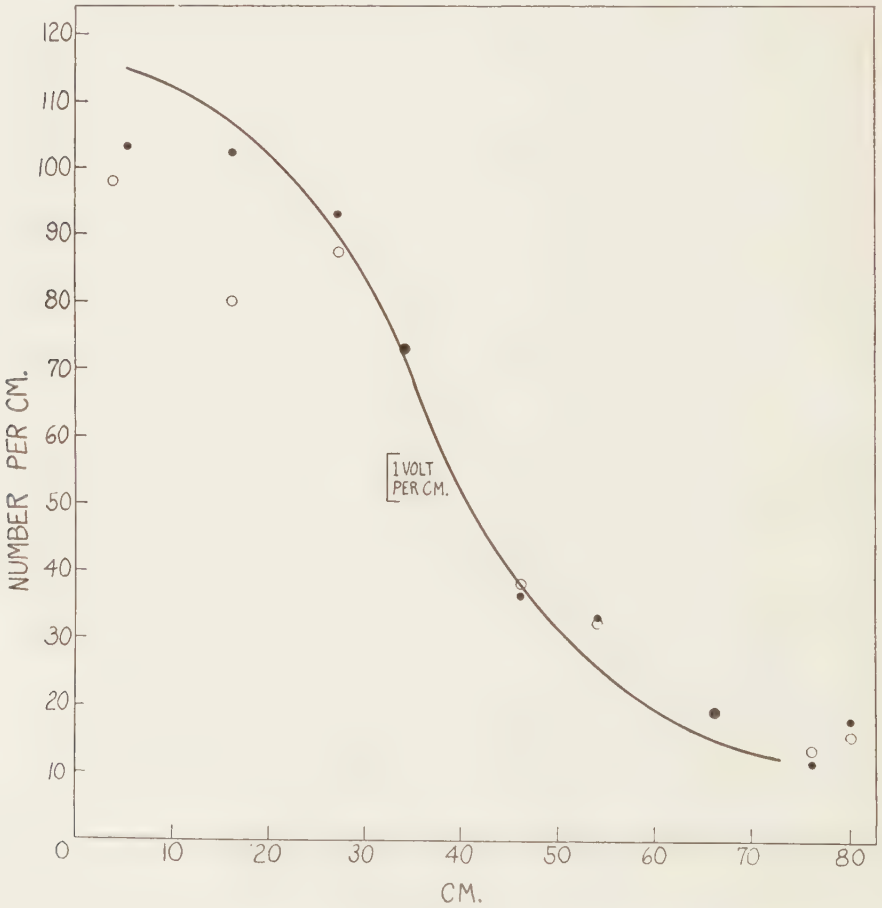
In Text-fig. 5, the plotted points show the cross-sectional area of the organs of Sachs and the curve shows the electromotive force per cm. of the minor discharge. The scales of area and electromotive force per cm. are not the same as in Text-fig. 4, but their ratio is the same. By choosing another value for this ratio, the points could be brought nearer to the curve, but the proportionality between the electromotive force per cm. and the cross-sectional area is by no means as clear as in the other case. On the other hand, the measurements are less dependable.

Transverse segments of the body of the fish were also divided sagittally, and the exposed surface of electric tissue was stained with methylene blue. The number of electroplaxes per cm. in the direction of the length of the fish, which is also the direction of the electric polarity, was counted under the microscope in each of the organs at various points along them. The septa of the electric tissue are tough but the matter they inclose is watery and

the tissue is therefore easily misshapen after being cut. This distortion of the cut surface could not be entirely prevented but was limited by mechanical means. The probable error of the count is estimated at less than 10 per cent along the greater part of the large organ and Hunter's organ, and somewhat more elsewhere.

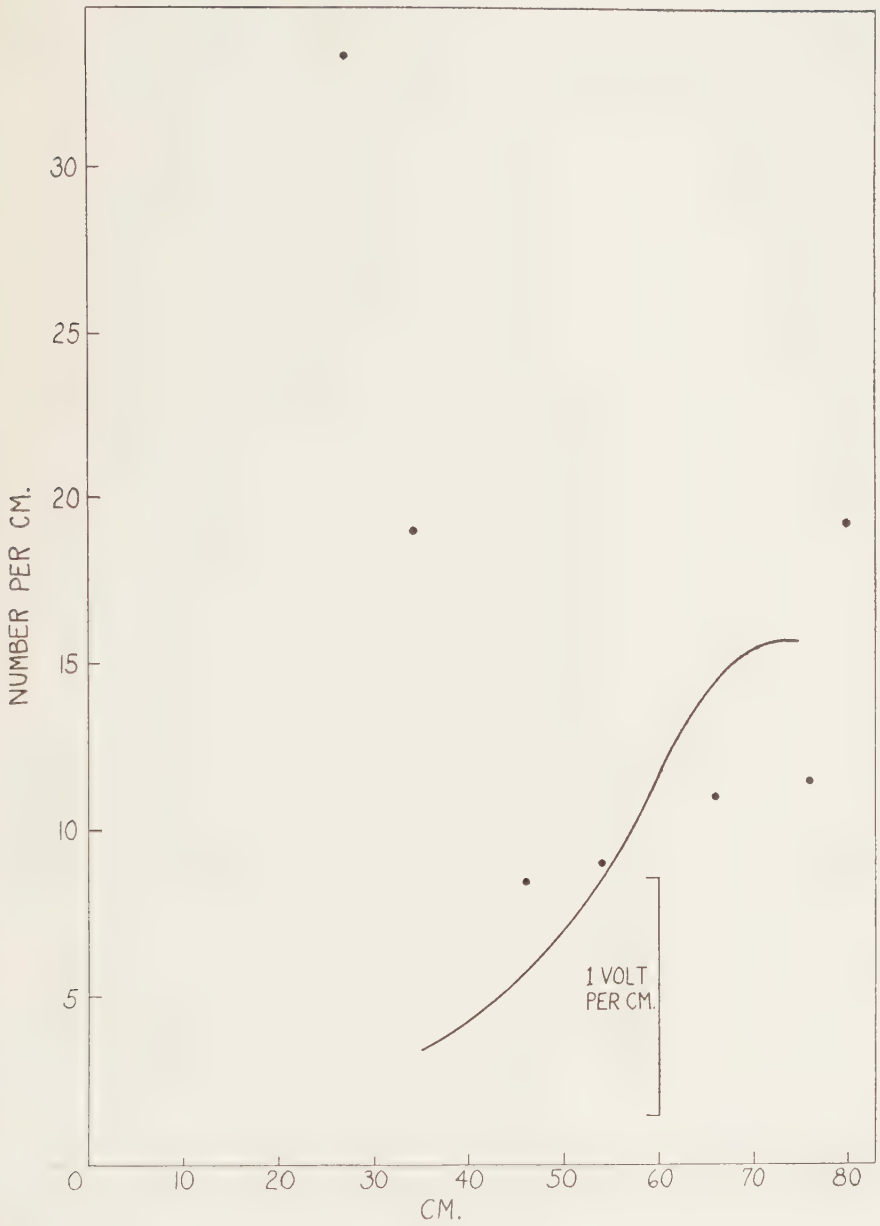
In Text-fig. 6, the black dots show the number of electroplaxes per cm. at various points along the large organ, and the white dots show the number per cm. along the organ of Hunter. Except at one place there is no difference between them too great to be a probable error of measurement. The curve showing the electromotive force per cm. of the major discharge is also drawn here for comparison. Again the plotted points fall rather close to the curve, and here the proportionality between the two plotted quantities has a clear enough meaning, which is simply that the electromotive force of one electroplax is at least roughly the same all along the organ. From the data plotted in Text-fig. 6 it is about 0.14 volt.

Dr. Kenneth S. Cole, using the needle technique, has found a change in potential during activity in the squid axon of 0.16 volt, and in *Nitella* of 0.1 volt. (Personal communication).



Text-fig. 6.

Curve: major discharge, electromotive force per cm. vs. distance along organs. Black dots: Large organ, number of electroplaxes per cm. vs. distance along organs. White dots: Hunter's organ, number of electroplaxes per cm. vs. distance along organs.



Text-fig. 7.

Curve: minor discharge, electromotive force per cm. vs. distance along organ. Dots: Sachs' organ, number of electroplaxes per cm. vs. distance along organs.

In the first of the papers referred to above[2], the opinion was tentatively offered that Hunter's organ produced the irregular discharge to which the name intermediate was given, the major and minor discharges being more positively ascribed to the large organ and Sachs' organ. But it was observed afterward and mentioned in the second paper[3] that the power of the intermediate discharge seemed too great to be generated in Hunter's organ alone.

It was concluded therefore that Hunter's organ produced no separate discharge though it might possibly produce an irregularity in the discharge of the large organ. The similarity in the structure of adjacent parts of Hunter's organ and the large organ now leads us to question whether the large organ ever discharges alone, without Hunter's organ, or whether, on the contrary, Hunter's organ is functionally a part of the large organ, only separated from it by connective tissue and the remnant of the lateralis imus.

In contrast to Hunter's organ, which is clearly separated from the large organ but closely similar to it in structure, the organ of Sachs is hardly separated at all from the large organ but over much of its length is clearly different in the size of the electroplaxes. At the two ends of Sachs' organ, however, the electroplaxes are about as many to the centimeter as in the adjacent parts of the large organ, and appear, at least with the crude staining and under the low magnification employed in these observations, to be practically identical with them. Especially toward the posterior end the organs become indistinguishable, the septum between them being no more marked than the septa within each organ. Toward the anterior end the two organs remain distinguishable by the sizes of the electroplaxes, at least until a place is reached at which the cross-section of Sachs' organ is very small indeed, containing only a few electroplaxes in parallel.

As shown by the points in Text-fig. 7, the number of electroplaxes per cm. in Sachs' organ has by far its highest value at the anterior end, where the electromotive force per cm. is low, according to the measurements previously described. This is a surprising finding, as it would imply that the single electroplax of Sachs' organ in this part has a much lower electromotive force than the neighboring and similar electroplax of the large organ. This seems so unlikely as to require further evidence before it can be accepted.

Preliminary measurements leading to the work here described were made in 1937 at the Museu Goeldi of Pará, Brazil, by the New York Aquarium-New York University Expedition to study the electric eel. It is a pleasure to acknowledge again the generous grant to this expedition made by the Doctor Simon Baruch Foundation and to express again our thanks to Dr. Godofredo Hagmann of the Museu Goeldi and to many others who aided the research at that time. The present data were obtained at the Biological Laboratory of the Long Island Biological Association at Cold Spring Harbor. We are very grateful to Dr. Eric Ponder and others at the Laboratory for the help and encouragement we received from them.

INDEX.

Names in **bold face** *indicate new genera, species or varieties; numbers in* **bold face** *indicate illustrations; numbers in parentheses indicate the paper containing the Plate numbers immediately following.*

A

Abylopsis tetragona, 304
Acanthephyra, 133
  acutifrons, 146, **146**
  anomala, 185
  brachytelsonis, 147
  brevirostris, 148, **149**, 154
  cucullata, 150
  curtirostris, 143, **144**
  eximimia, 147, **148**
  gracilipes, 149, **150, 151**
  haeckelii, 140, **141**
  indica, 150
  pulchra, 148
  purpurea, **134**, 141
  sibogae, 150
  sp. ?, 151
  stylorostrata, 144, **145**
  tenuipes, 150
Acanthodoras sp. 549
Acharax, 375
Acila, 388
  (Truncacila) castrensis, 388
Acinonyx jubatus, 276
Acipenser fulvescens, 549
  oxyrhynchus, 549
Actinothoe **californica**, 217, **217, 218**
  undata var. anguicoma, 217
Adrana, 389
  arcuata 407, 408
  crenifera 407, 408
  elongata, 407, 409, (25) **Plate II**
  exoptata, 407, 409, (25) **Plate II**
  janeiroensis, 408
  newcombi, 410
  penascoensis, 407, 410
  scaphoides, 411
  sowerbyana, 407, 410
  suprema, 407, 409, 411
  taylori, 407, 412
  tonosiana, 407, 412, (25) **Plate II**
Aegina citrea, 313
Aeginura **beebei**, 309, **310-312**
  grimaldii, 289, 309, 313
Aequidens moronii, 549
Agapornis sp. 273
Agelaius ruficapillus frontalis, 273
Agkistrodon blomhoffi, 270
  mokasen cupreus, 270
  piscivorous, 50, 270
Aidemosyne modesta modesta, 274
Ailuropoda melanoleuca, 261
Aix sponsa, 275
Ajaia ajaja, 272
Alces alces, 469
Alicia **beebei**, 211
Allacanthochasmus artus, 550
  varius, 550
Alligator mississipiensis, 34
Allocreadium sp., 550
Alopochen aegyptiacus, 468
Amazona barbadensis barbadensis, 272
  festiva festiva, 273
  ochrocephala oratrix, 272
    panamensis, 272
Ambloplites rupestris, 549
Amblyrhamphus holosericeus, 273
Ameiurus melas, 92
  nebulosus, 89, **91**, 92, 353, **355**, 549, 550, (8) **Plate I-VIII**
Amia calva, 549
Amnotragus lervia, 277, 278, 469
Amphicondrius granulosus, 337
Amphiodia sculptilis, 337
  urtica, 338
  vicina, 338, **338**
Amphipholis geminata, 336
  platydisca, 337
  squamata, 337
Amphiura arcystata, 336
Amphotistius sabinus, 550
Anas crecca carolinensis, 272
  platyrhynchos, 275, 468
    platyrhynchos, 275
  rubripes tristis, 275
Anguilla japonica, 264
Anodorhynchus leari, 273
Anoptichthys jordani, 113, (18) **Plates I-III**
Anthracoceros malabaricus malabaricus, 272
Anthracothorax violicauda violicauda, 273
Anthropoides paradisea, 274
Apharyngostrigea, 323
  bilobata, 323 (20) **Plate I**
  brasiliana, 324
  cornu, 325
  egretti, 324
  flexilis, 325
  garciai, 325
  ibis, 325
  repens, 325
  (?) simplex, 325
Arbacia incisa, 348
Arca adamsii, 423
Arctocephalus australis, 277
Ardea cinerea, 325
  goliath, 272
  herodias herodias, 323, 325
  nigra, 326
  purpurea, 325
Ardeola ibis ibis, 325

Argidia **alonia**, 84
azania, 84
hilaris, 84
Argulus spp. 552
Argusianus argus argus, 274
Arius aqua-dulce, 223
Arizona elegans elegans, 270
Asteroidea, 332
Astrapia rothschildi, 259
stephaniae stephaniae, 272
Astropecten armatus, 332
californicus, 332
Astropyga pulvinata, 348
Ateles cucullatus, 276
Atolla wyvillei, 315
Auripasser luteus, 274
Axis axis, 469

B

Badis badis, 549
Bagre marinus 221, **222, 224, 225, 229, 230, 232, 234, 236**, (13) **Plates I-V**
Balistes vetula, 549
Barbus lineatus, 549
Basiliscus vittatus, 34
Bentheocaris exuens, 145
Bianium plicitum, 550
Bitis gabonica, 271
Blarina brevicauda, 476, 477
Boa canina, 271
Boiga dendrophila, 270
Bothriocephalus cuspidatus, 551
Brachypternus benghalensis benghalensis, 272
Branchellion ravenelli, 551
Branta canadensis, 468
Brotogeris jugularis jugularis, 273
Bubo virginianus virgininanus, 272
Bucephalus pusillis, 550
Bunocephalus bicolor, 549
Buteo jamaicensis borealis, 273
Bycanistes cristatus, 272
sharpii duboisi, 273

C

Calamoichthys calabaricus, 549
Callinectes sapidus, 227
Calliobothrium verticillatum, 551
Callithrix penicillata, 277
Calcycopsis bigelowi, 290
birulai, 290
borchgrevinki, 290
chuni, 290
geometrica, 290
nematophora, 290
papillata, 290
prolifera, 303
simplex, 290
simulans, 290, 293
typa, 290
valdiviae, 290
Camallanus sp., 551
Camelus dromedarius, 278
Campostoma, 2, 6
anomalum, 6, 11
pullum, 7, 9
Cancellaria cumingiana, 371
Cancroma cochlearia, 324
Canis latrans, 278
Carassius auratus, 501, 552
Carcharias littoralis, 551
Cardium magnum, 371
Ca restricta, 86
Carpodacus mexicanus frontalis, 273
Casmerodius albus egretta, 272, 273
Cathaemasia famelica, 327
hians, 326
nycticoracis, 323, 325, (20) **Plate I**
reticulata, 326
spectabilis, 327
Catostomus commersonnii commersonnii, 10
Cebus capucina, 276
fatuellus, 466
Centromochlus aulopygius, 549
Cerastes cerastes, 270, 271
Cerococebus fulginosus, 466
torquatus, 276
Cercopithecidae, 513
Cercopithecus grivet, 466
mona cambelli, 276
mozambicus, 466
sabaeus, 276, 466
Cervus axis, 276
canadensis canadensis, 276
duvauceli, 278
eldi, 277
elephas, 469
hortulorum, 277
unicolor, 277
Chaenobryttus gulosus
Chaetodipterus faber, 549
Channa asiatica, 549
Cheirodon piaba, 549
Chelydra serpentina serpentina, 47
Chiarella centripetalis, **294, 295**
Chilodon sp., 550
Chilomycterus schoepfii, 550
Chlorophonia frontalis frontalis, 272
Chlorostilbon caribaeus caribaeus, 273
Choephaga magellanica, 468
Choeropsis liberiensis, 277
Chondrancanthopsis nodosus, 551
Chromatonema erythrogonon, 297, **298**
hertwigi, 297
rubrum, 297
Chrysolophus pictus, 274
Cichlasoma festivum, 549
uropthalmus, 116
ericymba, 116
Ciconia alba, 326
ciconia ciconia, 273
Circus cyaneus hudsonius, 273
macrurus, 325
Cirrhites aprinus, 58
graphidopterus, 58
Cirrhitichthys aureus, 61
corallicola, 58, **60**
Cirrhitus, 54
betaurus, 55
rivulatus, 54, **56**, 64, (5) **Plate I**
Clethrionomys gapperi, 477
Clinostomum campanulatum, 323, 327, 551
Clinostomus elongatus, 7
Clypeaster europacificus, 349
ochrus, 350

speciosus, 350
Coliuspasser albonotatus, 272
Colobonema typicum, 302
Coluber constrictor constrictor, 36
Columba livia, 272
Constrictor constrictor constrictor, 270
Corallobothrium sp., 551
Corturnix corturnix, 467
Corvus brachyrhynchos brachyrhynchos, 274
Costelloleda, 398
Crepidostomum sp., 550
Crinifer piscator, 273
Crossobothrium laciniatum, 551
Crossoptilon mantchuricum, 273
Crossophus fodiens, 484
Crotalidae, 49
Crotalus atrox atrox, 270
cerastes, 271
horridus atricaudatus, 270
viridis viridis, 46, 270
Cryptocotyle lingua, 551
Ctenophthalmus pseudagyrtis, 488, 490
Ctenops vittatus, 549
Ctenossaura acanthura, 271
Cunina proboscidea, 306
prolifera, 303, 306
Cunoctona lanzerotae, 309
myosura, 311
nausothoe, 309
Cyanerpes cyaneus, 275
Cyclochaeta domerqui, 550
Cygnus olor, 273, 468
Cyprinodontidae, 9
Cyrilla, 389
adamsi, 420
munita, 419
(neopleurodon) subdolus, 420

D

Dama dama, 277, 469
Dascyllus aruanus, 549
Dasyatis hastatus, 551
Dasypus novemcinctus texanus, 278
Dendroaspis augusticeps, 270
viridis, 270
Dendrocygna autumnalis autumnalis, 275
discolor, 275
Dendrolagus ursinus, 523
Didelphis virginiana, 276
Diodon hystrix, 549
Diopederma danianum, 343
Diplectanus sp., 550
Dissoura episcopus microcelis, 274
Distoma cornu, 324
Distomum simplex, 324
Dithadama ? **domarita**, 87
Doratopsylla blarinae, 488, 490
Dromiceius novaehollandiae novaehollandiae, 275
Drosophila athabascae, 27
azteca, 27
lancefieldi, 26
melanogaster, 27
miranda, 27
pseudoobscura, 23
Drymarchon corais couperi, 270

E

Echinometra vanbrunti, 349
Elaphe obsoleta obsoleta, 37
quadrivittata quadrivittata, 270
vulpina, 38
Electrophorus electricus, 249, 553, (14) **Plate I**
Ennucula, 382
Ephyrina, 173
bifida, **174**
hoskynii, **173**
Epibdella melleni, 526, 550
Epicrates cenchris, 271
Epinephelus striatus, 549
Ergasilidae (Spp?), 552
Ergasilus sp., 552
Erithizon dorsatum dorsatum, 277
Erythrocebus patas, 278
Esomus malayensis, 549
(Esox), estor, 551
Esoxlucius, 2
masquinongy, 549
Etroplus suratensis, 549
Eucidaris thouarsii, 347
Euglyphis **marbodia**, 85
Eumedusa similis, 290
Eunectes murinus, 270
Euphractus sexcinctus, 277
Euplectes franciscana franciscana, 273
orix orix, 275
Eupomotis gibbosus, 353, **354**, 550, (23) **Plates I, II**
Eutiara mayeri, 284
Exoglossum, 4, 8
maxillingua, 6, 7, 11

F

Felis cacomitli, 278
cougar, 276
leo, 278
pardalis, 276
Florida caerulea, 272
Forbesella (Chologaster) agassizii, 115
Fundulus bermudae, 97, 98, **99, 100**
heteroclitis, 550

G

Galago alleni, 436
crassicaudatus, 436
montieri, 440
demidoffii, 436
senegalensis moholi, 433, (27) **Plates I-VI**
Galeichthys felis, 221, **222, 225, 229, 230, 232, 234, 236,** 549, (13) **Plates I-V**
milberti, 235
Gallus gallus, 467
gallus, 273
Gambusia afinis, 501
afinis, 108
holbrooki, 97, **99**, 106, **107, 109**
Gennaeus leucomelanos melanotus, 274
nycthemerus, 467
swinhoii, 467
Ginglymostoma cirratum, 549
Gonostoma elongatum, 127, 136, 175
Gorilla berengei, 519
gorilla, 513
Grus canadensis tabida, 275

Guttera edouardi edouardi, 272
Gymnoderus foetidus, 274
Gymnothorax funebris, 549
  moringa, 549
Gymnotis coatesi, 549

H

Halichaeres radiatus, 549
Halicreas minimum, 302
Hapale pygmaea, 276
Harengula pensacolae, 22
Helioperca macrochira, 549, 550
Heloderma horridum, 271
  suspectum, 271
Hemitragus jemlahicus, 276
Hemixus flavala flavala, 275
Henneguya acerinae, 92
  ameiurensis, 89, 90, **91**, 92, 552, (8) **Plates I-VIII**
  exilis, 93
  gurleyi, 92
Herichthys cyanoguttatus, 549
Herodias timorensis, 325
Holostomum repens, 324
Huro salmoides, 549, 551
Hybognathus regius, 10
Hyborhynchus notatus, 551
Hyelaphus porcinus, 470
Hylosia **derica**, 85
Hymenodora glacialis, 176, 179
  gracilis, 175, **176**
Hyphessobrycon heterorhabdus, 549
  serpae, 549

I

Ichthyophthirius multifiliis, 527, 550
Ictalurus punctatus, 93, 551
Iguana iguana rhinolapha, 270
Ilyoplax pusillus, 66

J

Jupiteria, 402

K

Kakatoe galerita galerita, 274
  roseicapilla roseicapilla, 274
  sanguinea goffini, 274
Katadesmia, 413
Kittocincla malabarica malabarica, 274
Koiropotamus koiroptamus kenlae, 277

L

Lagothrix humboldtii, 277
  ingumatus, 277
Lama vicugna, 278
Lampropeltis getulus floridana, 40, 270
    geiulus, 271
    splendida, 271
    subsp., 270
Larus argentatus smithsonianus, 273
  atricilla, 274
  novaehollandiae novaehollandiae, 274
Lebistes, 98
  reticulatus, **99**, 109, **110**, **111**
Lecithaster lindbergi, 264
Leda agapea, 394
  electa, 412
  fortis, 402
  inornata, 404
  metcalfi, 408
  pontonia, 403
  sowerbyana, 411
  taylori, 411
Lepisosteus osseus, 549
Lepomis auritis, 329, 364, 549 (21) **Plate I**
  cyanellus, 364
Leptochela bermudensis, **131**, 132
Leptoptilus crumenifer, 327
Leptotila cassini cassini, 274
Lernae sp., 552
Lernaeenicus radiatus, 551
Leuckartiara gardineri, 284
  zacae, 284, **285**, **286**
Leucosomus corporalis, 6, 7, 11, 363
Leucotmenis **kaietura**, 87
Ligula intestinalis, 551
Linckia colombiae, 334
Lintonium vibex, 550
Liriope tetraphylla, 302
Lophortyx californica californica, 274
Lophura rufa, 273
Lovenia cordiformis, 352
Lucaya bigelowi, 189, **190**
Luidia asthenosoma, 332
  bellonae, 332
  foliolata, 333
  ludwigi, 333
Lutra canadensis vaga, 277
Lytechinus anamesus, 348
  pictus, 348

M

Macaca irus, 276, 466, 513
  mulatta, 276, 466, 515
  nemestrina, 276
Macaria **barticaria**, 86
Macrophthalmus depressus, 66
  dilatatus, 66
  japonicus, 66
Macropus giganteus giganteus, 277
Malletia, 389, 420
  elongata, 422
  faba, 423
  gigantea, 421
  inequalis, 423
  magellanica, 424
  (Malletia) chilensis, 421
  (Minormalletia) arciformis, 423
  (Minormalletia) benthina, 423
  (Neilo) goniura, 422
  patagonica, 424
  peruviana, 424
  truncata, 424
Medusa mollicina, 304
  pilearis, 304
Megaceryle alcyon, 326
Megalaima virens marshallorum, 274
Megayoldia, 414
Meleagris gallopava silvestris, 272
Melopsittacus undulatus, 274
Melozone leucotis, 272
Menidia menidia, 551
Meningodora mollis, 165
Meoma grandis, 352
Mephitis nigra, 276

Microcotyle sp., 550
Microglanis parahybae, 549
Microgonia **hildonia**, 87
Micropterus dolomieu, 551
Microtus pennsylvanicus, 477
Minormalletia, 422
Moenkhausia pittieri, 549
Moira clotho, 350
Mollienisia sphenops, 98, **99**, **101-105**
  ssp., 104
Monolepis albicans, 67
  inermis, 66, 67, 70, 81
  orientalis, 67
Morone interrupta, 549, 550
Mugil curema, 237
Munia atricapilla atricapilla, 274
Muntiacus muntjak, 469
Murex recurvirostris, 217
Musophaga violacea violacea, 274
Mustelus canis, 551
Myadestes unicolor, 275
Mycteroperca bonaci, 549
Mylossoma duriventris, 549
Myxobolus cf. linearis, 92
  sp., 550

N

Naja hannah, 27
  naja, 270
  nivea, 270
Napaeozopus insignis, 477
Narcine brasiliensis, 431
Nasua nasua, 276
Natrix cyclopion floridana, 42
  erythrogaster transversa, 43
  septemvittata, 44
  sipedon pictiventris, 45
    sipedon, 9
Neascus vancleavi, 551
Neila, 422
Nemanthidae, 212
Nemanthus, 212
  californicus, **214**, 215, **216**
  nitidus, **213**, 214, **216**
Nematobothrium sp., 550
Neochasmus umbellus, 550
Neopleurodon, 419
Neoturris **crockeri**, 287, **287-289**
Nidorellia armata, 333
Nocomis, 2, 6, 7
  biguttatus, 6, 361
  micropogon, 6, 361
Notemigonus crysoleucas, 495
Notiopsar curaeus, 274
Notophoyx novaeholliandiae, 325
Notostomus, 152
  beebei, 168
  compsus, **156**, **157**
  distirus, **166**, **167**
  fragilis, 165
  gibbosus, 170
  japonicus, 168
  longirostris, 172
  marptocheles, 158, **159**, **160**
  miccylus, 161 **162**, **163**
  mollis, 164, **165**
  murrayi, 168
  patentissimus, 172
  perlatus, 170, **171**
  robustus, 168, **169**
  vescus, 153, **154**
  westergreni, 171, **172**
Notropis cornutus, 1, 361, (1) **Plates I-IV**
  chryocephalus, 2, 5, 10
    cornutus, 1, 5, 362
    frontalis, 2, 4
  hudsonius hudsonius, 10
  pilsbryi, 361
  x rubellus, 7, 361, 362
Nucolopsis, 383
Nucula, 379
  abrupta, 422
  agujana, 379, 384
  cahuitensis, 381
  chrysocoma, 380, 385
  colombiana, 379, 385
  crenulata, 380
  darwini, 411
  dorbignyi, 408
  (Ennucula) cardara, 379, 383
  (Ennucula ?) linki, 379, 383
  (Ennucula) tenuis, 379, 382
  grayi, 379, 385
  hilli, 384
  iphigenia, 380, 386
  lanceolata, 411
  miliaris, 418
  (Nucolopsis) **schencki**, 384, (25) **Plate I**
  (Nucula) declivis, 380, (25) **Plate I**
  (Nucula) exigua, 380, 381
  obliqua, 382
  panamina, 379, 386
  paytensis, 380, 381, 386
  pigafettae, 380, 386
  pisum, 379, 387
  proxima, 427
  savatieri, 379, 387
  schencki, 380
  semiornata, 380, 387
  suprastriata, 380
  taeniolata, 380, 387
  tanneri, 379, 388
Nuculana, 378, 390
  acapulcensis, 394, (25) **Plate I**
  acrita, 391, 402
  agapea, 391 402
  bicostata, 391, 394, 402
  cestrota, 399
  cordyla, 390, 401
  (Costelloleda) costellata, 390, 398, (25) **Plate II**
  (Costelloleda) **marella**, 390, 399, (25) **Plate II**
  crispa, 391, 403
  cuneata, 391, 403
  elaborata, 401
  excavata, 391, 404
  flexuosa, 399
  hamata, 390
  hindsii, 391, 404
  lobula, 392, 404
  loshka, 390, 404
  lucasana, 392, 405
  lyrata, 395
  media, 394
  ornata, 391, 405

oxia, 391, 405
peruviana, 390, 405
(Politolida) polita, 391, 394
pontonia, 391, 406
pyriformis, 394
rhytida, 392, 406
(Saccella) acuta, 390, 392, (25) **Plate I**
(Saccella) callimene, 391, 393, (25) **Plate I**
(Saccella) eburnea, 391, 395, (25) **Plate II**
(Saccella) elenensis, 391, 393, 394, (25) **Plate I**
(Saccella) gibbosa, 392, 395, (25) **Plate II**
(Saccella) impar, 391, 396, (25) **Plate II**
(Saccella) laeviradius, 391, 396, (25) **Plate II**
(Saccella) taphria, 391, 397
(Spinula) calcar, 391
(Spinula) calcarella, 391
(Thestyleda) cordyla, 400
(Thestyleda) hamata, 400, (25) **Plate III**
Nuculidae, 378
Nuculanidae, 389
Nycticorax nycticorax hoactli, 323, 325
Nymphicus hollandicus, 274

O

Ocypode, 65
albicans, 66, 69, 70, **71, 74-80**
gaudichaudii, 66, 67, **68, 75, 77-80**
occidentalis, 66, 69, 70, **74-80**
Odocoileus virginianus leucurus, 470
nemoralis, 469
osceola, 276
Oodinium ocellatum, 536, 550
Opheodrys aestivus, 35
Ophiactis savignyi, 339
simplex, 340
Ophiocoma aethiops, 341
alexandri, 341
Ophioderma panamense, 341
teres, 342
variegatum, 343
Ophiolepis **fulva, 345**
grisea, 346
variegata, 344
Ophiomyxa panamensis, 336
Ophionereis annulata, 340
nuda, 340
Ophiophragmus, 338
Ophiopteris papillosa, 341
Ophiothela gracilis, 340
Ophiothrix spiculata, 340
Ophiozona pacifica, 344
Ophisaurus apodus, 35
Ophiura lutkenii, 343
Opisthonema oglinum, 227
Oplophorus, 132, 184
foliaceus, 185
gracilirostris, 188
grimaldii, 187, **188**
spinicauda, 184, **185**
Oreaster occidentalis, 333
Orthoyoldia, 414
Ostinops viridis, 272
Othilia aculeata, 334, (22) **Plate I**
Otobothrium crenacolle, 551
Otolicnus garnetti, 442
Ovalipes ocellatus, 227

P

Padda oryzivora, 275
Pandarus bicolor, 551
Pandea conica, 284
rubra, 287
Papio anubis, 276
papio, 466
Paracalops, 477
breweri, 489
Paradisaea gulielmi, 273
Paradoxurus hemaphroditus, 278
Parapandalus, 192
richardi, **192**
zurstrasseni, 194
Paroaria nigrigenis, 274
Parotia lawesi lawesi, 257, 273
sefilata, 257
wahnesi, 257, **257, 259**
Parapasiphae, 126
macrodactyla, 126, **128**, 129
sp. a., 126, **129**
sp. b., 126, **130**
sulcatifrons, 126
Pasiphaea alcocki, 123
amplidens, 126
corteziana, 123
hoplocerca, 124, 125
liocerca, 122, 123
longispina, 123, 126
orientalis, 126
rathbunae, 123
scotiae, 123, 126
Patiria miniata, 333
Pavo cristatus, 275, 467
var., 274
Pegantha clara, **305, 306**
martagon, 308
smaragdina, 305
triloba, 308
Pegasia dodecagona, 304
Pelagia noctiluca, 315
Pelecypoda, 373
Penella instructa, 551
Perca flavescens, 549, 551
Periphylla hyacinthina, 314
Peromyscus, 22
leucopus noveboracensis, 477, 489
maniculatus, 489
Petrasmus, 377
Phalacrocorax auritis auritis, 327
Pharia pyramidata, 334
Pharomachrus mocinno mocinno, 273
Phasianus colchicus versicolor, 274
Phassus **guianensis**, 88
Phastolomis mitchelli, 277
Phataria unifascialis, 335
Philortyx fasciatus, 274
Photostomias guernei, 127
Physetocaris microphthalma, 196, **197, 198**
Pionites melanocephala melanocephala, 274
Pitta sordia cucullata, 274
Pituophis melanoleucus melanoleucus, 39, 271
sayi sayi, 270
Pitymys pinetorum scalopsoides, 477
Placobdella parasitica, 551
Plagiobrissus grandis, 351
pacificus, 351, (22) **Plate I**

Plagusia depressa tuberculata, 66, 70, 72
Plectropterus gambensis niger, 273
Plesionika martia, 190, **191**
Plethodon cinereus, 481
Pleurodon, 418
  adamsii, 418
  cinctus, 418
  dobergensis, 418
  gunteri, 418
  hedleyi, 418
  microdus, 418
  ovalis, 419
  woodi, 418
  zinndorfi, 418
Ploceus vitellinus vitellinus, 275
Pocillopora, 342
Poecilidae, 97
Podocotyle atmon, 265
  atzi, 263, 265, **266**, 550 (17) **Plate I**
Pogonias cromis, 549
Politoleda, 397
Polycolpa forskalii, 303
Polyorchis penicillata, 296
Polyxenia cyanostylis, 304
Pomoxia sparoides, 549
Pongo pygmaeus, 466
Pontobdella muricata, 551
Poronotus tricanthus, 551
Porphyrio poliocephalus poliochephalus, 272
Potos flavus, 278
Prepiella **deicoluria**, 88
Prionotus scitulus, 227
Pristella riddlei, 549
Procavia capensis, 277
Probliotrema sp., 550
Proteocehphalus pinguis, 551 (33) **Plate V**
  sp., 551
Protrichomonas sp., 550
Pseudbarydia **elipha**, 83
Pseudemys floridans ssp., 48
Pseudocirrhites, 53
  pinos, 61, **62**
Psittacula eupatria nipalensis, 274
Psittacus erithacus erithacus, 273
Ptilinopus jambu, 273
Ptyas mucosus, 270
Pucrasia macrolopha macrolopha, 272
Python curtus, 270
  molurus molurus, 270
  regius, 271
  reticulatus, 270

R

Ramphostos discolorus, 274
  piscivorous brevicarinatus, 272
  swainsonii, 273
Ramplocelus carbo carbo, 275
Rasbora maculata, 549
  heteromorpha, 549
  trilineata, 549
Rhinicythys atratulus atratulus, 9, 10, 14 (1) **Plates II-IV**
  cataractae, 7
Rhinocheilus lecontei, 41
Rhodeus amarus, 353
Rhynchotus rufescens rufescens, 275
Rhynochetos jubatus, 273
Rhyticeros subruficollis, 272
Roccus lineatus, 549
  saxatilis, 237
Rubigula dispar, 274
Rypticus saponaceus, 549

S

Saccella, 392
Sagittarius serpentarius, 272
Saiga tatarica, 277
Salvelinus fontinalis, 549
Sarcophilus harrissii, 276
Sarda sarda, 550
Scaphirhyncus platorhyncus, 549
Scardinius erythrophthalmus, 549
Scatophagus argus, 549
Schizoderma diplax, 343
Scleoporous undulatus fasciatus, 34
Sciaenops ocellatus, 549
Sclerasterias alexandri, 335
  crassia var., 335
  heteropaes, 335
  var., 335
Scopimera globosa, 66
Scorpaena madurensis, 263, 264, 265, 550, (17) **Plate I**
Scyllarides latus, 551
Sebastes marinus, 551
Semotilus, 2, 6, 7
  atromaculatus atromaculatus, 6, 7, 9, 11, 14 (1) **Plate I**
Seriola zonata, 549
Serranus cabrilla, 237
Serrasalmus scapularis, 549
Sigsbeia lineata, 336
Sika nippon, 468
Simiidi, 513
Solemya, 374
  (Acharax) agassizii, 375
  (Acharax) dalli, 375
  (Acharax) johnsoni, 376
  (Acharax) macrodactyla, 376
  (Acharax) patagonica, 376
  australis, 374
  borealis, 377
  mediterranea, 374
  parkinsonii, 374
  (Petrasma) panamensis, 377
  (Petrasma) valvulus, 378
  (Solemya) lomitensis, 374
  tokunagai, 376
  yessoensis, 376
Solemyarina velesiana, 374
Solenella gigantea, 421
Solenodon paradoxus, 276
Solmissus albescens, 308
  incisa, 308
  marshalli, 308
Sorex araneus, 473
    granti, 473
  cinereus, 474
  dispar, 474
  fumeus fumeus, 473 (29) **Plates I-IV**
  minutus, 485
  vulgaria, 480
Sparus macrocephalus, 264
Spheroides maculatus, 550

Sphyrion lumpi, 551
Sphyrna zygaena, 551
Spinitectis sp.,
Spinula, 401
Spinus tristis tristis, 274
Stephanoproproides, 326
Sternotherus odoratus, 47
Sterrhurus branchialis, 550
Stizostedion vitreum, 550
Stomolophus agaricus, 316
  meleagris, 316
Stomotoca divisa, 283
  pterophylla, 283
Streptopelia decaocto decaocto, 272
Strongylocentrotus purpuratus, 349
Storeria dekayi, 41
Stylocidaris dubius, 347
Suricata suricatta, 277
Sylvacapra grimmi, 277
Symbranchus marmoratus, 549
Synaptomys cooperi, 477
Systellaspis, 179
  braueri, **180**
  debilis, **181**, 195
  densispina, 180
  echinurus, 180

T

Tachysurus barbus, 227
Taeniopygia castanotis castanotis, 275
Tangara arthus, 272
  cyanoptera, 273
  cyaneicollis hannahiae, 272
  flava cayana, 273
  guttata guttata, 275
  heinei, 272
  icterocephala, 274
  larvata centralis, 273
  mexicana mexicana, 273
  violacea violacea, 273
  xanthogaster exsul, 275
Tarpon atlanticus, 493, 549 (30) **Plates I, II**
Tautoga onitis, 551
Taxidea taxus taxus, 276
Taxus canadensis, 476
Terrapene carolina carolina, 4
Testudo tormieri, 48
Thalassoma bifasciatus, 549
Thamnophis sirtalis sirtalis, 46
Theristicus caudatus, 274
Thestyleda, 400
Thraupis cana cana, 274
Tiliapia mossambica, 549
Tindaria, 389, 425
  amabilis, 426
  atossa, 426
  compressa, 426
  mexicana, 427
  panamensis, 426
  salaria, 427
  smirna, 427
  thea, 427
  (Tindariopsis) sulculata, 425
  virens, 428
Tindariopsis, 425
Tolype **loisa**, 85
Taxopneustes roseus, 349
Trachinotus glaucus, 549
Tragelaphus angasi, 276
Tragopan caboti, 273
Trichechus manatus latirostrus, 550
Trichiurus lepturus, 550
Trichodina sp., 550
Trichoglossus haematod moluccanus, 274
Tridacna gigas, 373
Trimeresurus flavomaculatus, 270
Truncacila, 388
Tubulovesicula anguillae, 264, 265
  angusticauda, 265
  californica, 264, 265
  lindbergi, 265
  madurensis, 263, **264**, 265, 550 (11) **Plate I**
  muraenesocis, 264, 265
  pseudorhombi, 264, 265
  spari, 264, 265
Tupinambis teguixin, 271
Turdus merula merula, 272
  olivaceus olivaceus, 274
Tyto alba pratincola, 272

U

Uca minax, 66
  pugilator, 66
  pugnax, 66
Uraeginthus bengalus bengalus, 273
Urobrachya axillaris axillaris, 273
Ursus arctos arctos, 277

V

Varanus sp., 271
Venadicadia **cetiona**, 86
Vipera russelii, 270

X

Xenomystus nigri, 549
Xiphias gladius, 551

Y

Yoldia, 389, 412
  emersoni, 414
  (Katadesmia) vincula, 413
  (Megayoldia) martyria, 414
  (Orthoyoldia) panamensis, 415
  subaequilateralis, 421
  thracoaeformis, 416, 421
  (Yoldiella) cecinella, 416
  (Yoldiella) chilenica, 416
  (Yoldiella) dicella, 416
  (Yoldiella) granula, 416
  (Yoldiella) indolens, 417
  (Yoldiella) infrequens, 417
  (Yoldiella) leonilda, 417
  (Yoldiella) mantana, 417
Yoldiella, 415

Z

Zalophus californias, 277
Zapus hudsonius, 477
Zonurus giganteus, 270
Zygocanna costata, 301
  pleuronota, 301
  vagans, 299, **300**
Zygocannula, 301

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CONTENTS

Part 1. March 18, 1940.

PAGE

1. The Breeding Behavior of the Common Shiner, *Notropis cornutus* (Mitchill). By EDWARD C. RANEY. (Plates I-IV; Text-figure 1) 1
2. Divergence and Probability in Taxonomy. By ISAAC GINSBURG 15
3. Miscellaneous Notes on the Eggs and Young of Reptiles. By ROGER CONANT & ALEXANDER DOWNS, JR. 33
4. Occlusion of the Venom Duct of Crotalidae by Electro-coagulation: an Innovation in Operative Technique. By DUVAL B. JAROS. (Text-figure 1) 49
5. Eastern Pacific Expeditions of the New York Zoological Society. XVII. A Review of the American Fishes of the Family Cirrhitidae. By JOHN TEE-VAN. (Plate I; Text-figures 1-4) 53
6. Eastern Pacific Expeditions of the New York Zoological Society. XVIII. On the Post-embryonic Development of Brachyuran Crabs of the Genus *Ocypode*. By JOCELYN CRANE. (Text-figures 1-8) 65
7. New Species of British Guiana Heterocera. By W. SCHAUS.. 83
8. A Papillary Cystic Disease Affecting the Barbels of *Ameiurus nebulosus* (Le Sueur), Caused by the Myxosporidian *Henneguya ameiurensis* sp. nov. By R. F. NIGRELLI & G. M. SMITH. (Plates I-VIII; Text-figure 1) 89
9. Caudal Skeleton of Bermuda Shallow Water Fishes. IV. Order Cyprinodontes: Cyprinodontidae, Poecilidae. By GLORIA HOLLISTER. (Text-figures 1-17) 97
10. The Histology of the Eye of the Cave Characin, *Anoptichthys*. By E. B. GRESSER & C. M. BREDER, JR. (Plates I-III) 113

Part 2. July 3, 1940.

11. Plankton of the Bermuda Oceanographic Expeditions. IX. The Bathypelagic Caridean Crustacea. By FENNER A. CHACE, JR. (Text-figures 1-64) 117
12. Eastern Pacific Expeditions of the New York Zoological Society. XIX. Actiniaria from the Gulf of California. By OSKAR CARLGREN. (Text-figures 1-8) 211
13. Morphological and Embryological Studies on Two Species of Marine Catfish, *Bagre marinus* and *Galeichthys felis*. By DANIEL MERRIMAN. (Plates I-V; Text-figures 1-9) 221

PAGE

14. Propagation of the Electric Impulse Along the Organs of the Electric Eel, *Electrophorus electricus* (Linnaeus). By C. W. COATES, R. T. COX, W. A. ROSENBLITH & M. VERTNER BROWN. (Plate I; Text-figures 1-3) 249

15. Notes on the Display Forms of Wahne's Six-plumed Bird of Paradise. By LEE S. CRANDALL. (Text-figures 1-3) 257

16. Acute Hemorrhagic Gastro-enteritis in a Giant Panda. By LEONARD J. GOSS 261

17. Two New Species of Trematodes from the Deep Sea Scorpion Fish, *Scorpaena madurensis* Cuv. & Val. By ROSS F. NIGRELLI. (Plate I; Text-figures 1 & 2) 263

18. Report of the Hospital and Laboratory of the New York Zoological Park, 1939. Mortality Statistics of the Society's Collection. By LEONARD J. GOSS 269

Part 3. November 14, 1940.

19. Eastern Pacific Expeditions of the New York Zoological Society. XX. Medusae of the Templeton Crocker and Eastern Pacific *Zaca* Expeditions, 1936-1938. By HENRY B. BIGELOW. (Text-figures 1-20) 281

20. Two New Species of Trematodes (*Apharyngostrigea bilobata*: Strigeidae, and *Cathaemasia nycticoracis*: Echinostomidae) from Herons, with a Note on the Occurrence of *Clinostomum companulatum* (Rud.). By O. WILFRED OLSEN. (Plate I) 323

21. Nesting of the Sunfish, *Lepomis auritus* (Linnaeus), in Tidal Waters. By NEIL D. RICHMOND. (Plate I) 329

22. Eastern Pacific Expeditions of the New York Zoological Society. XXI. Notes on Echinoderms from the West Coast of Central America. By HUBERT LYMAN CLARK. (Plates I & II; Text-figures 1-4) 331

23. The Nesting Behavior of *Eupomotis gibbosus* (Linnaeus), In a Small Pool. By C. M. BREDER, JR. (Plates I & II; Text-figures 1 & 2) 353

24. Reproductive Activities of a Hybrid Minnow, *Notropis cornutus* × *Notropis rubellus*. By EDWARD C. RANEY 361

Part 4. December 31, 1940.

25. Eastern Pacific Expeditions of the New York Zoological Society. XXII. Mollusks from the West Coast of Mexico and Central America. Part I. By LEO GEORGE HERTLEIN & A. M. STRONG. (Plates I & II) 369

26. On the Electric Powers and Sex Ratios of Foetal *Narcine brasiliensis* (Olfers). By C. M. BREDER, JR., & STEWART SPRINGER 431

PAGE

27. A Study of the Activities of a Pair of *Galago senegalensis moholi* in Captivity, Including the Birth and Postnatal Development of Twins. By FLORENCE DE L. LOWTHER. (Plates I-VI) 433

28. Diets for a Zoological Garden: Some Results During a Test Period of Five Years. By HERBERT L. RATCLIFFE 463

29. The Biology of the Smoky Shrew (*Sorex fumeus fumeus* Miller). By W. J. HAMILTON, JR. (Plates I-IV; Text-figure 1) 473

30. Social and Respiratory Behavior of Small Tarpon. By ARTHUR SHLAIFER & C. M. BREDER, JR. (Plates I & II; Text-figure 1) 493

31. New Observations on the Blood Group Factors in Simiidi and Cercopithecidae. By P. B. CANDELA, A. S. WIENER & L. J. GOSS 513

32. Muscle Dystrophy in Tree Kangaroos Associated with Feeding of Cod Liver Oil and Its Response to Alpha-Tocopherol. By LEONARD J. GOSS 523

33. Mortality Statistics for Specimens in the New York Aquarium, 1939. By ROSS F. NIGRELLI. (Plates I-III) 525

34. A Comparison of Some Electrical and Anatomical Characteristics of the Electric Eel, *Electrophorus electricus* (Linnaeus). By R. T. COX, W. A. ROSENBLITH, JANICE A. CUTLER, R. S. MATHEWS & C. W. COATES. (Text-figures 1-7) .. 553

Index to Volume XXV 563

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